

## **A.2.4 PUGET SOUND CHINOOK SALMON**

**Primary contributors: Mary Ruckelshaus and Norma Jean Sands  
(Northwest Fisheries Science Center)**

The status of Puget Sound chinook salmon was formally assessed during a coastwide status review (Myers et al. 1998). In November 1998, a BRT was convened to update the status of this ESU by summarizing information received since that review and comments on the 1997 status review (NMFS 1998). The following section (“*Summary of Previous BRT Conclusions*”) summarizes the findings and conclusions made at the time of the 1998 status review update; the section after that (“*Summary of New Information*”) reports on new information received through March, 2003 and the conclusions of the 2003 BRT based on the new information.

### **A.2.4.1. Summary of Previous BRT conclusions**

#### **Status and trends**

The BRT concluded in 1998 that the Puget Sound chinook ESU was likely to become endangered in the foreseeable future. The estimated total run size of chinook salmon to Puget Sound in the early 1990s was 240,000 chinook, down from an estimated 690,000 historical run size. The 5-year geometric mean of spawning escapement of natural chinook salmon runs in North Puget Sound during the period from 1992-1996 was approximately 13,000. Both long- and short-term trends for these runs were negative, with few exceptions. In south Puget Sound, spawning escapement of the natural runs averaged 11,000 spawners at the time of the last status review update. In this area, both long- and short-term trends were predominantly positive. In Hood Canal, spawning populations in six streams were considered a single stock by the co-managers because of extensive transfers of hatchery fish (WDF et al. 1993). Fisheries in the area were managed primarily for hatchery production and secondarily for natural escapement; high harvest rates directed at hatchery stocks resulted in failure to meet natural escapement goals in most years (USFWS 1997a). The 5-year geometric mean natural spawning escapement at the time of the last update was 1,100, with negative short- and long-term trends (except in the Dosewallips River). The ESU also includes the Dungeness and Elwha Rivers, which have natural chinook salmon runs as well as hatcheries. The Dungeness River had a run of spring/summer-run chinook salmon with a 5-year geometric mean natural escapement of 105 fish at the time of the last status review update. The Elwha River has a 5-year geometric mean escapement of 1,800 fish during the mid-1990s, which includes a large, but unknown fraction of naturally spawning hatchery fish. Both the Elwha and Dungeness populations exhibited downward trends in abundance in the 1990s.

#### **Threats**

Habitat throughout the ESU has been blocked or degraded. In general, upper tributaries have been impacted by forest practices and lower tributaries and mainstem rivers have been impacted by agriculture and/or urbanization. Diking for flood control, draining and filling of freshwater and estuarine wetlands, and sedimentation due to forest practices and urban development are cited as problems throughout the ESU (WDF et al. 1993). Blockages by dams,

water diversions, and shifts in flow regime due to hydroelectric development and flood control projects are major habitat problems in several basins. Bishop and Morgan (1996) identified a variety of critical habitat issues for streams in the range of this ESU, including changes in flow regime (all basins), sedimentation (all basins), high temperatures (Dungeness, Elwha, Green/Duwamish, Skagit, Snohomish, and Stillaguamish Rivers), streambed instability (most basins), estuarine loss (most basins), loss of large woody debris (Elwha, Snohomish, and White Rivers), loss of pool habitat (Nooksack, Snohomish, and Stillaguamish Rivers), and blockage or passage problems associated with dams or other structures (Cedar, Elwha, Green/Duwamish, Snohomish, and White Rivers). The Puget Sound Salmon Stock Review Group (PFMC 1997a) provided an extensive review of habitat conditions for several of the stocks in this ESU. It concluded that reductions in habitat capacity and quality have contributed to escapement problems for Puget Sound chinook salmon, citing evidence of direct losses of tributary and mainstem habitat due to dams, and of slough and side-channel habitat due to diking, dredging, and hydromodification. It also cited reductions in habitat quality due to land management activities.

WDF et al. (1993) classified 11 out of 29 stocks in this ESU as being sustained, in part, through artificial propagation. Nearly 2 billion fish have been released into Puget Sound tributaries since the 1950s (Myers et al. 1998). The vast majority of these have been derived from local returning fall-run adults. Returns to hatcheries have accounted for 57% of the total spawning escapement, although the hatchery contribution to spawner escapement is probably much higher than that, due to hatchery-derived strays on the spawning grounds. Almost all of the releases into this ESU have come from stocks within this ESU, with the majority of within ESU transfers coming from the Green River Hatchery or hatchery broodstocks that have been derived from Green River stock (Marshall et al. 1995). The electrophoretic similarity between Green River fall-run chinook salmon and several other fall-run stocks in Puget Sound (Marshall et al. 1995) suggests that there may have been a significant effect from some hatchery transplants. Overall, the pervasive use of Green River stock throughout much of the extensive hatchery network that exists in this ESU may reduce the genetic diversity and fitness of naturally spawning populations.

Harvest impacts on Puget Sound chinook salmon stocks were quite high. Ocean exploitation rates on natural stocks averaged 56%-59%; total exploitation rates averaged 68%-83% (1982-89 broodyears) (PSC 1994). Total exploitation rates on some stocks have exceeded 90% (PSC 1994).

Previous assessments of stocks within this ESU have identified several stocks as being at risk or of concern (reviewed in Myers et al. 1998).

### **A.2.4.2 New Data and Updated Analyses**

#### **ESU status at a glance**

Historical peak run size	~690,000
Historical populations	31
Extant populations	22

5-year geometric mean natural spawners per population	222 – 9,489 (median = 766)
Long-term trend per population	0.92 – 1.2 (median = 1.0)
Recent $\lambda$ (H1) per population	0.67 – 1.2 (median = 1.0)

**Listing status**

Threatened

**ESU structure**

The Puget Sound ESU is comprised of 31 historically quasi-independent populations of chinook, 22 of which are believed to be extant currently (Puget Sound TRT 2001 and 2002). The populations that are presumed to be extinct are mostly of early-returning fish, and most of these are in the mid- to southern parts of the Puget Sound or in Hood Canal/Strait of Juan de Fuca (Table A.2.4.1). The populations in the ESU with the greatest estimated fractions of hatchery fish tend to be in the mid- to southern parts of Puget Sound, in Hood Canal, and in the Strait of Juan de Fuca (Table A.2.4.2).

Table A.2.4.1. Historical populations of chinook salmon in the Puget Sound ESU (PSTRT 2001). Run-timing types for each population and the biogeographic region within which each population occurs also are noted (Puget Sound TRT 2001 and 2002).

Population	Status	Run-Timing	Bio-Geographic Region	Reference
N. Fork Nooksack	Extant	early	Strait of Georgia	
S. Fork Nooksack	Extant	early	Strait of Georgia	
Nooksack late	<i>Extinct</i>	late	Strait of Georgia	1
Lower Skagit	Extant	late	Whidbey Basin	
Upper Skagit	Extant	late	Whidbey Basin	
Lower Sauk	Extant	late	Whidbey Basin	
Upper Sauk	Extant	early	Whidbey Basin	
Suiattle	Extant	early	Whidbey Basin	
Upper Cascade	Extant	early	Whidbey Basin	
N. Fork Stillaguamish	Extant	late	Whidbey Basin	
S. Fork Stillaguamish	Extant	late	Whidbey Basin	
Stillaguamish early	<i>Extinct</i>	early	Whidbey Basin	2,3
Skykomish	Extant	late	Whidbey Basin	
Snoqualmie	Extant	late	Whidbey Basin	
Snohomish early	<i>Extinct</i>	early	Whidbey Basin	2,3
Cedar	Extant	late	Main Basin/ South Basin	
N. Lake Washington	Extant	late	Main Basin/ South Basin	
Green/Duwamish	Extant	late	Main Basin/ South Basin	
Green/Duwamish early	<i>Extinct</i>	early	Main Basin/ South Basin	2,3
Puyallup	Extant	late	Main Basin/ South Basin	
White	Extant	early	Main Basin/ South Basin	
Puyallup early	<i>Extinct</i>	early	Main Basin/ South Basin	2
Nisqually	Extant	late	Main Basin/ South Basin	
Nisqually early	<i>Extinct</i>	early	Main Basin/ South Basin	2,4
Skokomish	Extant	late	Hood Canal	
Skokomish early	<i>Extinct</i>	early	Hood Canal	2,3,5
Dosewallips	Extant	late	Hood Canal	
Dosewallips early	<i>Extinct</i>	early	Hood Canal	2,4
Dungeness	Extant	late	Strait of Juan de Fuca	
Elwha	Extant	late	Strait of Juan de Fuca	
Elwha early	<i>Extinct</i>	early	Strait of Juan de Fuca	2,3

1=PS TRT 2001; 2= Nehlsen et al. 1991; 3= WDF et al. 1993; 4= ONRC 1995; 5= Deschamps 1954

New information obtained for the 22 populations of chinook salmon in the Puget Sound ESU is summarized in Appendix A.5.2. Sources of data and detailed information on data years are provided for each population separately in the Appendix.

### **Abundance of natural spawners**

The most recent 5-year (1998-2002) geometric mean of natural spawners in populations of Puget Sound chinook salmon ranges from 222 (in the Dungeness) to almost 9,500 fish (in the upper Skagit population). Most populations contain natural spawners numbering in the high hundreds (median recent natural escapement = 766); of the ten populations with greater than 1,000 natural spawners, only two are thought to have a low fraction of hatchery fish (Table A.2.4.2; Figure A.2.4.1). Estimates of the fraction of natural spawners that are of hatchery origin are sparse—data are available for only twelve of the 22 populations in the ESU, and such information is available for only the most recent 5-10 years (Table A.2.4.2). Estimates of the hatchery fraction of natural spawners come from counts of otolith-marked local hatchery fish sampled from carcasses (Nooksack River Basin, Snohomish River Basin), adipose fin clip counts from redd count surveys (Skagit River Basin), and coded-wire tag sampling (NF Stillaguamish and Green River). In general, populations in the Skagit river basin are the only ones with presumed low estimates of naturally spawning hatchery fish. The Stillaguamish and Snohomish populations have moderate estimates of naturally spawning hatchery fish. Estimates of historical equilibrium abundance from predicted pre-European settlement habitat conditions range from 1,700 to 51,000 potential chinook salmon spawners per population (Moberg 2000). The historical estimates of equilibrium abundance are several orders of magnitude higher than realized spawner abundances currently observed throughout the ESU.

Table A.2.4.2. Abundance of natural spawners, estimates of the fraction of hatchery fish in natural escapements, and estimates of historical capacity of Puget Sound streams (Puget Sound TRT, unpublished data and Puget Sound co-managers).

Population	Geometric mean natural spawners (1998-2002)	Arithmetic mean natural spawners (1998-2002) (min, max)	Geometric mean natural-origin spawners (1998-2002)	Average % hatchery fish in escapement <sup>5</sup> 1997-2001 (min, max since 1992)	Chinook salmon hatcheries in basin?	Hatchery fraction data? (years)	EDT estimate of historical abundance <sup>3</sup>
NF Nooksack <sup>1</sup>	1,538	2,275 (366-4,671)	125	91 (88 – 95)	Kendall (NF; rm 45)	Yes (1995-2002)	26,000
SF Nooksack <sup>1</sup>	338	372 (157-620)	197	40 (24 - 55)	Kendall (NF; rm 45)	Yes (1999-2002)	13,000
Lower Skagit	2,527	2,833 (1,043-4,866)	2,519	0.2 (0 – 0.7)	Marblemount (mouth of Cascade) <sup>a</sup>	Yes (1998-2001)	22,000
Upper Skagit	9,489	10,468 (3,586-13,815)	9,281	2 (2 – 3)	Marblemount (mouth of Cascade) <sup>a</sup>	Yes (1995-2000)	35,000
Upper Cascade	274	329 (83-625)	274	0.3	Marblemount (mouth of Cascade) <sup>a</sup>	No (assume low)	1,700
Lower Sauk	601	669 (295-1,103)	601	0	Marblemount (mouth of Cascade) <sup>a</sup>	Yes (2001)	7,800
Upper Sauk	324	349 (180-543)	324	0	Marblemount (mouth of Cascade) <sup>a</sup>	No (assumed)	4,200
Suiattle	365	399 (208-688)	365	0	Marblemount (mouth of Cascade) <sup>a</sup>	No (assumed)	830
NF Stillaguamish	1,154	1,172 (845-1,403)	671	40 (13 – 52)	Tribal (NF)	Yes (1988-1999)	24,000

SF Stillaguamish	270	272 (243-335)	NA	NA	Tribal (NF)	none	20,000
Skykomish	4,262	4,286 (3,455-4,665)	2,392	40 (11 - 66)	Wallace R.	Yes (1979-2001)	51,000
Snoqualmie	2,067	2,229 (1,344-3,589)	1,700	16 (5 – 72)	Wallace R.	Yes (1979-2001)	33,000
NL Washington	331	351 (227-537)	NA	NA	Lake Wash, Issaquah, UW	none	NA
Cedar	327	394 (120-810)	NA	NA	Lake Wash, Issaquah, UW	none	NA
Green	8,884	9,286 (6,170-13,950)	1,099	83 (35 -100)	Soos, Icy and Keta Cr.	Yes (1989-1997)	NA
White <sup>2</sup>	844	1,039 (316-2,002)	NA	NA	White R (rm 23); Voights Cr. (Carbon R), Diru (rm 5)	none	NA
Puyallup	1,653	1,679 (1,193-1,988)	NA	NA	Voights Cr. (Carbon R), Diru (rm 5)	none	33,000
Nisqually	1,195	1,221 (834-1,542)	NA	NA	Kalama, Clear Cr	none	18,000
Skokomish	1,392	1,437 (926-1,913)	NA	NA	George Adams (Purdy Cr., lower Skok)	none	NA
<i>Dosewallips</i> <sup>4</sup>	48	50 (29-65)	NA	NA	<i>none</i>	<i>none</i>	4,700

<i>Duckabush</i> <sup>4</sup>	43	57 (20-151)	NA	NA	none	NA
<i>Hamma Hamma</i> <sup>4</sup>	196	278 (32-557)	NA	NA	none	NA
Mid Hood Canal	311	381 (95-762)	NA	NA	none	NA
Dungeness <sup>2</sup>	222	304 (75-663)	NA	NA	Dungeness (and Hurd Cr)	8,100
Elwha <sup>*6</sup>	688	691 (633-813)	NA	NA	Tribal (rm 1) and State (rm 3.2)	NA

\*2002 natural escapement data not available

<sup>1</sup>NF Nooksack natural escapement counts include estimated numbers of spawners from the MF Nooksack since the late 1990s and chinook salmon returning to the NF hatchery that were released back into the NF to spawn; SF Nooksack natural escapement estimates contain naturally spawning hatchery fish from the “early” and “late” run hatchery programs in the Nooksack River Basin.

<sup>a</sup>Previous summer-run chinook salmon hatchery program discontinued--last returns in 1996; current summer-run program (initiated in 1994) collects hatchery broodstock from spawners in upper Skagit River.

<sup>2</sup>Captive broodstock program for “early” run chinook salmon ended in 2000; estimates of natural spawning escapement include an unknown fraction of naturally spawning hatchery-origin fish from “late” and “early” run hatchery programs in the White and Puyallup river basins.

<sup>3</sup> Estimates of historical equilibrium abundance based on an EDT analysis conducted by the co-managers in Puget Sound (PSRT 2002).

<sup>4</sup> The Puget Sound TRT considers chinook salmon spawning in the Dosewallips, Duckabush and Hamma Hamma rivers to be sub-populations of the same historically independent population; annual counts in those 3 streams are variable due to inconsistent visibility during spawning ground surveys.

<sup>5</sup>Estimates of the fraction of hatchery fish in natural spawning escapements are from the Puget Sound TRT database; Green River estimates are from Marianna Alexandersdotir, NWIFC, unpublished data.

<sup>6</sup>Estimates of natural escapement do not include volitional returns to the hatchery or those fish gaffed or seined from spawning grounds for broodstock collection



## Trends in natural spawners

Long-term trends in abundance for naturally spawning populations of chinook salmon in Puget Sound indicate that approximately half of the populations are declining and half are increasing in abundance over the length of available time series (Table A.2.4.3; Figure A.2.4.1). The median over all populations of long-term trend in abundance is 1.0 (range 0.92 – 1.2), indicating that most populations are just replacing themselves. The most extreme declines in natural spawning abundance have occurred in the combined Dosewallips and Elwha populations over the long term. Those populations with the greatest long-term population growth rates are the North Fork Nooksack and the White. All of the populations reported above are likely to have a moderate-high fraction of naturally spawning hatchery fish, so it is not possible to say what the trends in naturally spawning, natural-origin chinook salmon might be in those populations.

Fewer populations exhibit declining trends in abundance over the short term than over the long term—4 of 22 populations in the ESU are declining from 1990-2002 (median = 1.06, range = 0.96-1.4) (Table A.2.4.3). In contrast, estimates of short-term population growth rates suggest a very different picture when the reproductive success of hatchery fish is assumed to be 1. As discussed in the *Methods* section, short-term population growth rates ( $\lambda$ ) were calculated under two assumptions about the reproductive success of naturally spawning hatchery fish: the reproductive success was 0 (H0), or the reproductive success was equivalent to that of natural-origin fish (H1). Short-term  $\lambda$  estimates assuming the reproductive success of hatchery fish was 0 are very similar to estimates of short-term trend, so they are not reported here. The median short-term  $\lambda$  over all populations (when the reproductive success of hatchery fish is assumed to be 1) is  $\lambda$ -H1 = 1.0 (range = 0.67-1.2).

The median estimate of short-term population growth would be even lower if the estimates of the fraction of naturally spawning hatchery fish were available for all populations in the ESU. As mentioned earlier, the 10 populations in the ESU for which no hatchery fraction information is available are all suspected to have a moderate-to-high fraction of hatchery-origin adults in natural escapements. In those cases where hatchery information is available and the fraction of hatchery-origin natural spawners is significant (e.g., North Fork Nooksack, Green River), the effect of the reproductive success of hatchery fish assumption on estimates of  $\lambda$  is dramatic. The most extreme short-term declines in natural spawner abundance have occurred in the Upper Sauk, Cedar, Puyallup, and Elwha populations. Of these populations, only the Upper Sauk is likely to have a low fraction of hatchery fish in escapements. When  $\lambda$  is calculated assuming the reproductive success of hatchery fish is equivalent to that of natural-origin fish, the biggest estimated short-term population declines are in the Green, Skykomish, North Fork Stillaguamish and North Fork Nooksack populations (Table A.2.4.3). Again, if hatchery fraction data were available for the additional 10 populations in the ESU for which such data are missing, more examples of significant short-term declines in population growth rate surely would emerge. The populations with the most positive short-term trends and population growth rates are the combined Dosewallips and White River populations. Both of these populations are thought to have a moderate fraction of naturally spawning hatchery fish, but since such estimates are not available, estimating the trends in natural-origin spawners is not possible.

Another indicator of the productivity of chinook salmon populations is presented in the time series figure showing the total number of spawners (natural and hatchery origin) and the number of preharvest recruits produced by those spawners against time (Figure A.2.4.2). Dividing the number of preharvest recruits by the number of spawners for the same time period would yield an estimate of the preharvest recruits per spawner. Generating this type of figure requires harvest and age structure information and therefore could be produced for only a limited number of years in some populations. Representing information this way can indicate if there have been changes in preharvest recruitment and the degree to which harvest management has the potential to recover populations. If the preharvest recruitment line is consistently below the spawner line, it indicates that the population would not be replacing itself, even in the absence of all harvest. In most populations, the preharvest recruits exceeded spawners in all but a few years for which data are available (Figure A.2.4.2).

Table A.2.4.3. Estimates of long- and short-term trends and the short-term median population growth rate ( $\lambda$ ), and their 95% confidence intervals for spawners in Puget Sound chinook salmon populations (data are from the Puget Sound TRT, unpublished data). Long and short-term trends are calculated on all spawners; short-term  $\lambda$  is calculated assuming the reproductive success of naturally spawning hatchery fish is equivalent to that of natural-origin fish (for those populations where information on the fraction of hatchery fish in natural spawning abundance is available).

<b>Population</b>	<b>Data years</b>	<b>LT Trend (CI)</b>	<b>ST Trend (CI) (1990-2002)</b>	<b>ST <math>\lambda</math> (<math>\pm</math> lnSE) (1990-2002)</b>
N. Fork Nooksack	1984-2001	1.16 (1.04-1.30)	1.42 (1.18-1.70)	0.75 (0.07)
S. Fork Nooksack	1984-2001	1.00 (0.96-1.05)	1.07 (0.98-1.15)	0.94 (0.05)
Lower Skagit	1952-2002	0.99 (0.97-1.00)	1.06 (0.94-1.18)	1.05 (0.09)
Upper Skagit	1952-2002	1.00 (0.99-1.01)	1.06 (0.98-1.14)	1.05 (0.06)
Upper Cascade	1984-2002	1.04 (1.00-1.08)	1.05 (0.98-1.14)	1.06 (0.05)
Lower Sauk	1952-2002	0.99 (0.98-1.00)	1.03 (0.91-1.17)	1.01 (0.12)
Upper Sauk	1952-2002	0.97 (0.96-0.99)	0.97 (0.89-1.06)	0.96 (0.06)
Suiattle	1952-2002	0.99 (0.98-0.99)	1.00 (0.92-1.08)	0.99 (0.06)
N. Fork Stillaguamish	1974-2002	1.01 (0.99-1.03)	1.06 (1.01-1.11)	0.92 (0.04)
S. Fork Stillaguamish <sup>1</sup>	1974-2002	1.02 (1.00-1.04)	1.00 (0.97-1.02)	0.99 (0.02)
Skykomish	1965-2002	0.99 (0.98-1.00)	1.07 (1.03-1.11)	0.87 (0.03)
Snoqualmie	1965-2002	1.03 (1.01-1.04)	1.10 (1.01-1.21)	1.00 (0.04)
N. Lake Washington <sup>1</sup>	1983-2002	0.97 (0.91-1.03)	1.04 (0.91-1.19)	1.07 (0.07)
Cedar <sup>1</sup>	1965-2002	0.97 (0.95-0.98)	0.97 (0.89-1.07)	0.99 (0.07)
Green <sup>1</sup>	1968-2002	1.02 (1.01-1.04)	1.05 (0.98-1.13)	0.67 (0.06)

White <sup>1</sup>	1970-2002	1.05 (1.00-1.10)	1.14 (1.06-1.22)	1.16 (0.06)
Puyallup <sup>1</sup>	1968-2002	1.02 (1.00-1.04)	0.96 (0.91-1.02)	0.95 (0.06)
Nisqually <sup>1</sup>	1968-2002	1.02 (0.99-1.05)	1.06 (0.93-1.20)	1.04 (0.07)
Skokomish <sup>1</sup>	1987-2002	0.99 (0.93-1.05)	1.04 (0.97-1.12)	1.04 (0.04)
Combined Dosewallips <sup>1</sup>	1968-2002	0.96 (0.93-0.98)	1.11 (0.99-1.20)	1.17 (0.10)
Dungeness <sup>1</sup>	1986-2002	1.02 (0.94-1.10)	1.07 (0.94-1.20)	1.09 (0.11)
Elwha <sup>1</sup>	1986-2001	0.92 (0.84-1.00)	0.97 (0.86-1.10)	0.95 (0.11)

<sup>1</sup>Estimate of the fraction of hatchery fish in time series is not available for use in  $\lambda$  calculation, so trend represents that in hatchery-origin + natural-origin spawners.

## Updated threats information

The Puget Sound TRT (unpublished data) has estimated adult equivalent exploitation rates for each population of chinook salmon in the ESU (Table A.2.4.4). Exploitation rates are the proportion of the returning population that are caught in fisheries or are killed as a result of fishing activities (e.g., non-retention mortality). These harvest estimates include mortality from sport and commercial fisheries in the ocean, Puget Sound, and in rivers. Exploitation rate estimates are a function of coded-wire tag (i.e., CWT) recoveries, escapement estimates, and estimates of incidental mortalities provided by the Chinook Technical Committee (CTC 2001). These harvest rates are equivalent to exploitation rates provided by the CTC, but they are different from exploitation rates estimated by the FRAM model.

Exploitation rates on Puget Sound chinook salmon populations averaged 75% (median = 85%; range 31-92%) in the earliest 5 years of data availability and have dropped to an average of 44% (median = 45; range 26-63%) in the most recent 5-year period.

Table A.2.4.4. Estimated brood-year adult-equivalent exploitation rates on populations of Puget Sound chinook salmon (Puget Sound TRT unpublished data).

Population	Data years (brood year)	Earliest 5-year mean exploitation rate (%)	Most recent 5-year mean exploitation rate (%)
N. Fork Nooksack	1982 - 1998	43	26
S. Fork Nooksack	1982 - 1998	44	26
Lower Skagit <sup>1</sup>	1969 - 1998	86	61
Upper Skagit <sup>1</sup>	1969 - 1998	88	63
Upper Cascade <sup>1</sup>	1982 - 1998	80	56
Lower Sauk <sup>1</sup>	1969 - 1998	88	63
Upper Sauk <sup>1</sup>	1979 - 1998	72	56
Suiattle <sup>1</sup>	1979 - 1998	73	58
N. Fork Stillaguamish	1972 - 1998	89	40
S. Fork Stillaguamish	1972 - 1998	89	40

Skykomish	1969 - 1998	86	49
Snoqualmie	1969 - 1998	85	45
N. Lake Washington	1981 - 1998	40	27
Cedar	1969 - 1998	52	31
Green	1969 - 1998	82	57
White	1972 - 1998	90	26
Puyallup	1971 - 1998	53	30
Nisqually	1977 - 1998	92	62
Skokomish	1985 - 1998	90	31
Dosewallips	1985 - 1998	92	38
Dungeness	1984 - 1998	31	32
Elwha	1984 - 1998	64	44

<sup>1</sup>The population-specific harvest rates for the Skagit River Basin are in dispute; Puget Sound TRT, NOAA Fisheries Northwest Regional Office, and the Puget Sound co-managers are working to resolve different estimates resulting from the Pacific Salmon Commission (Chinook Technical Committee) and the FRAM model.

The Puget Sound TRT (unpublished data) has amassed estimates of the total number of hatchery-origin chinook salmon returning to streams (Table A.2.4.5). These estimates for each population include the total return—returns to natural spawning grounds and to hatchery racks within a population’s geographic boundaries. These estimates do not account for possible strays of hatchery fish from outside the population’s boundaries. It is apparent from Table A.2.4.5 that even populations of chinook salmon in northern Puget Sound (not a hatchery production management area for co-managers) receive significant numbers of adult hatchery fish returning each year. The numbers of hatchery-origin juvenile chinook salmon released into Puget Sound streams each year also are reported in Table A.2.4.5. Average annual numbers of juvenile releases have declined since the time of the last Status Review (1990-1994 vs. 1995-2001) in the Nooksack, Skagit and Green river basins, and releases have remained roughly the same in the north Lake Washington/Cedar, White/Puyallup and in south Puget Sound streams. In contrast, juvenile chinook salmon releases have increased in the Snohomish and Elwha river basins, in eastern Kitsap streams, and in Hood Canal. With the exception of the Skagit and Stillaguamish river basins, all major watersheds in Puget Sound receive annual releases of over a million (close to 7 million in Hood Canal) juvenile chinook salmon. Hatchery stocks of chinook salmon in Puget Sound have been categorized (SSHAG 2003) and are provided in Appendix A.5.1.

Table A.2.4.5. Total estimated recent annual average returns of hatchery-produced chinook salmon (adults returning to hatchery racks and to spawning grounds) and total releases of juvenile chinook salmon in streams containing independent populations of chinook salmon in Puget Sound (Puget Sound TRT and B. Waknitz, unpublished data).

Population	Average annual return to stream 1987–2001 (min-max) <sup>1</sup>	Previous (1990-1994) average annual releases of chinook salmon hatchery juveniles by life-stage (in thousands)	Most recent (1995-2001) average annual releases of chinook salmon hatchery juveniles by life-stage (in thousands)
N. Fork Nooksack	1,720 (0 – 9,179)	5,500 (4,763 fall; 737 spring/summer)	3,081 fall
S. Fork Nooksack	1,254 (0 – 5,515)		
Lower Skagit	1,171 (70 – 4,110)	2,251 (1,292 fall; 491 spring, 468 summer)	754 (32 fall; 423 spring; 299 summer)
Upper Skagit			
Upper Cascade			
Lower Sauk			
Upper Sauk	318 (2 – 777)	NA	178 summer
Suiattle			
N. Fork Stillaguamish	NA	1,926 (1,316 fall; 610 summer)	2,574 (1,401 fall; 1,173 summer)
S. Fork Stillaguamish <sup>2</sup>	NA		
Skykomish	3,666 (824 – 8,530)	2,349 fall	2,077 fall
Snoqualmie	2,921 (19 – 6,514)		
N. Lake Washington <sup>2</sup>	NA	4,413 fall	3,681 fall
Cedar	NA		
Green	13,565 (3,211 – 23,014)	1,686 (1,672 fall, 14 spring) NA	1,695 (1,669 fall; 26 spring) NA
White <sup>2</sup>	NA		
Puyallup <sup>2</sup>	2,048 (762 – 3,484)		
Nisqually <sup>2</sup>	2,559 (0 – 13,481)	6,947 fall	6,411 fall
Misc. south	NA		
Puget Sound streams	NA	2,851(2,519 fall; 332 spring)	3,771 (3,447 fall; 324 spring)
Eastern Kitsap streams			
Skokomish <sup>2</sup>	3,621 (294 – 8,816)	4,928 (4,637 fall; 291 spring)	6,856 (6,793 fall; 63 spring)
Comb.Dosewallips <sup>2</sup>	NA		
Dungeness <sup>2</sup>	NA	NA	1,283 spring
Elwha	634 (97 – 2,089)	1,831 fall	2,482 fall

<sup>1</sup>Hatchery rack-return data are not available for all streams.

<sup>2</sup>Estimates of hatchery-origin chinook salmon returning to spawn are not available.

### A.2.4.3. Comparison with Previous Data

Overall, the natural spawning escapement estimates for Puget Sound chinook salmon populations are improved relative to those at the time of the previous status review of Puget Sound chinook salmon conducted with data through 1997. The differences between population escapement estimates between the previous status assessments using data from 1997 and the present assessment using data through 2002 could be due to (1) revised pre-1997 data, (2) differences in which fish are counted as part of a population, (3) new information on the fraction of natural spawners that are hatchery fish, or (4) true differences reflected in new data on natural spawners obtained over the most recent 5 years. The median across populations of the most recent 5-year geometric mean natural escapement for the same 22 populations through 1997 was  $N = 438$  (compared to  $N = 771$  through 2002), and the range was 1-5,400. As was the case at the time of the previous status review, it is not possible to determine the status of the natural-origin, natural spawners in half of the populations of chinook salmon in Puget Sound. The most dramatic change in recent natural escapement estimates from the previous status assessment was in the Green River—the recent natural-origin escapement estimate is lower than the previous one by almost 5,000 spawners. This apparent drop in natural escapement is probably due primarily to new information about the fraction of hatchery fish that are spawning naturally.

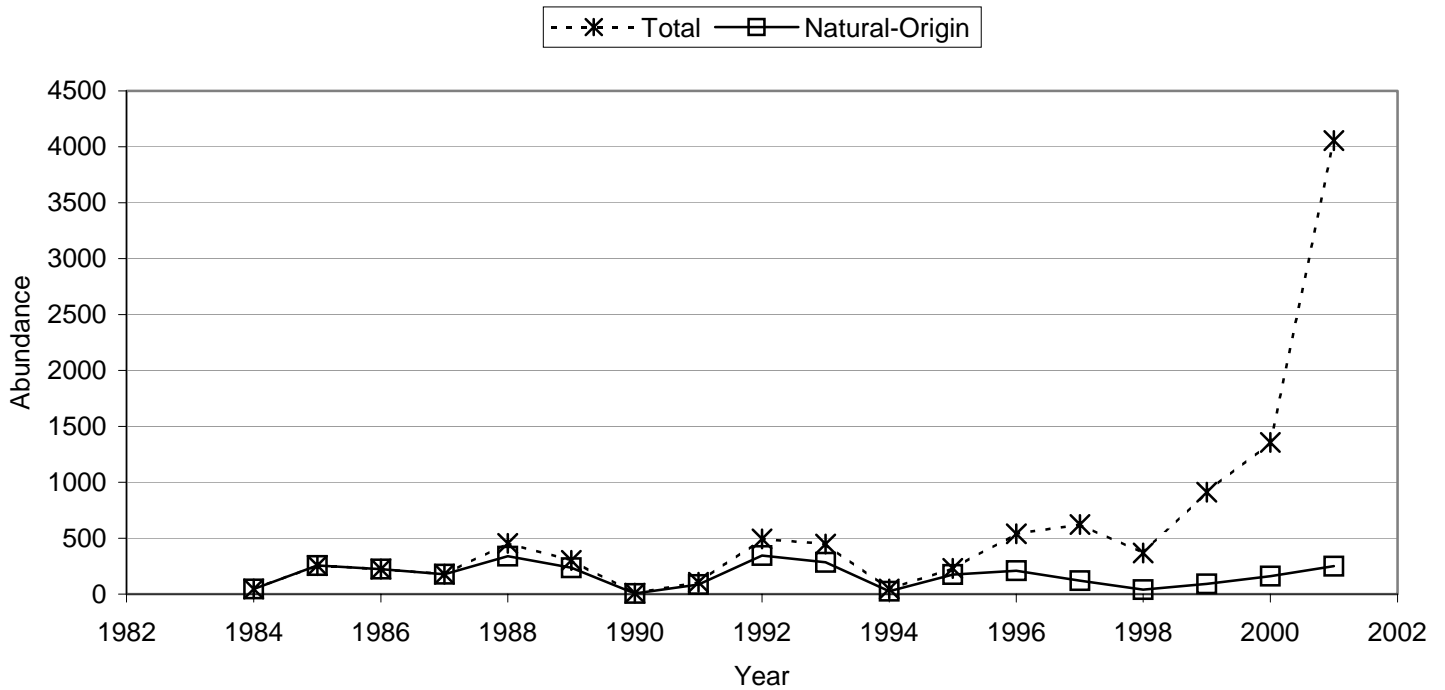
Throughout the ESU, the estimates of trends in natural spawning escapements for Puget Sound chinook salmon populations are similar to the previous status review of Puget Sound chinook salmon conducted with data through 1997. Some populations exhibit improvements in trends relative to the last status assessment, and others show more significant declines. As stated above for escapement estimates, the differences in trend estimates between the previous status assessments using data from 1997 and the present assessment using data through 2002 could be due to (1) revised pre-1997 data, (2) differences in which fish are counted as part of a population, (3) new information on the fraction of natural spawners that are hatchery fish, or (4) true differences reflected in new data on natural spawners obtained over the most recent 5 years. The median across populations of the long-term trend in natural spawners was a 1.1% decline per year through 1997, compared to a median estimate indicating a flat trend through 2002. Twelve populations had declining long-term trends through 1997, and 10 populations have declining long-term trends through 2002. Short-term trends are generally more positive in recent years—the median trend across 22 populations through 1997 was a 4% decline per year, and the median trend through 2002 was a 1.1% increase per year. Fourteen populations showed declining short-term trends at the time of the previous status reviews, and only four populations exhibit declining short-term trends in recent years. Nevertheless, as stated above for interpreting abundance estimates, we lack information on the fraction of naturally spawning, hatchery-origin fish for 10 of the 22 populations of chinook salmon in Puget Sound, so our understanding of the trend in natural-origin spawners among populations across the ESU is incomplete. An illustration of how misleading trend estimates on total natural spawners can be for estimating trends in natural-origin spawners can be found comparing the  $\lambda$  calculations assuming naturally spawning hatchery fish do (i.e.,  $\lambda - H1$ ) or do not (i.e.,  $\lambda - H0$ ) contribute naturally spawning offspring. For those 12 populations with information on the hatchery fraction of natural spawners in the ESU, 7 populations switched from an estimated positive short-term population growth rate to a negative one when hatchery fish were assumed to contribute naturally spawning offspring.

The spatial distribution of chinook salmon populations with a strong component of natural-origin spawners in the Puget Sound ESU has not changed since the time of the last status assessment. Populations containing significant numbers of natural-origin spawners whose status can be reliably estimated occur in the Skagit River Basin, the South Fork Stillaguamish, and the Snohomish River Basin. The remaining populations in mid- and south Puget Sound, Hood Canal and out the Strait of Juan de Fuca have significant (but non-quantifiable) fractions of hatchery-origin spawners, so their contribution to spatial structure in the ESU is not possible to estimate.

The change in diversity in the ESU from historical conditions also has not changed since the last status review. An estimated 31 independent populations of chinook salmon occurred historically in the ESU, and 22 remain extant. All but one of the 9 putatively extinct chinook salmon stocks is an early-run population (or component of a population). The loss of early-run chinook salmon stocks in Puget Sound represents an important loss of part of the evolutionary legacy of the historical ESU.

Figure A.2.4.1. Total and natural-origin spawner abundance estimates vs. year for populations of the Puget Sound chinook ESU.

### North Fork Nooksack



### South Fork Nooksack

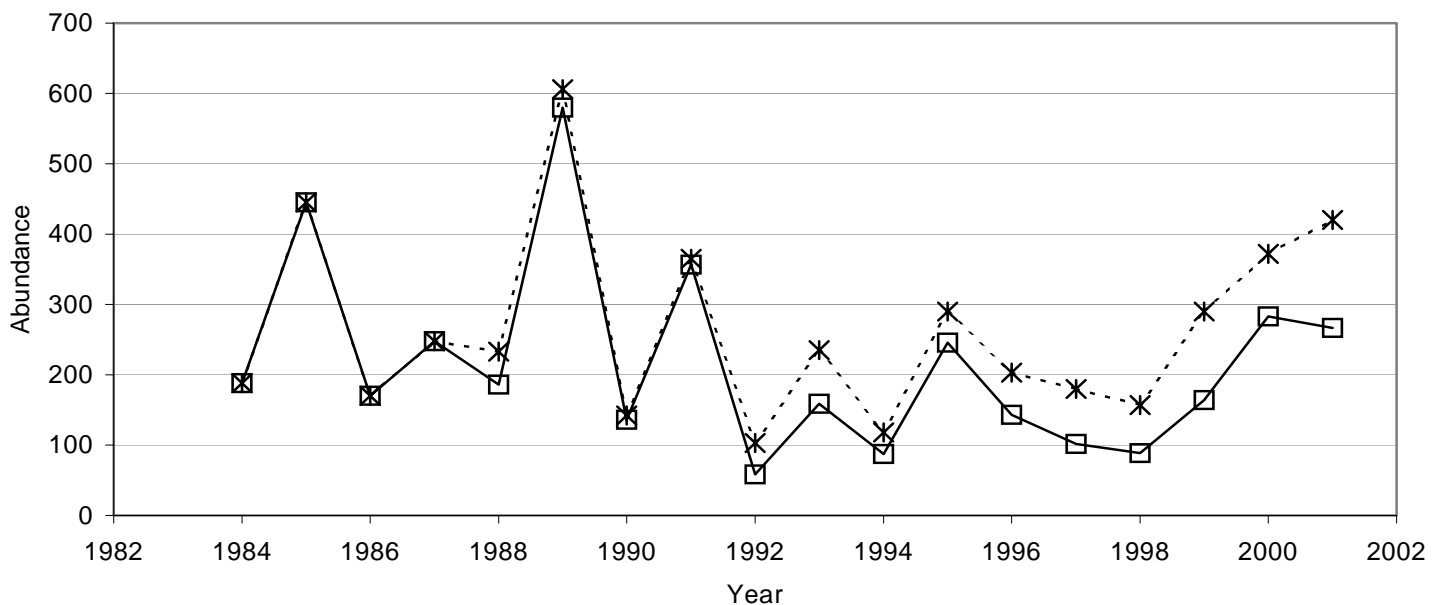




Figure A.2.4.1. Total and natural-origin spawner abundance estimates (cont.)

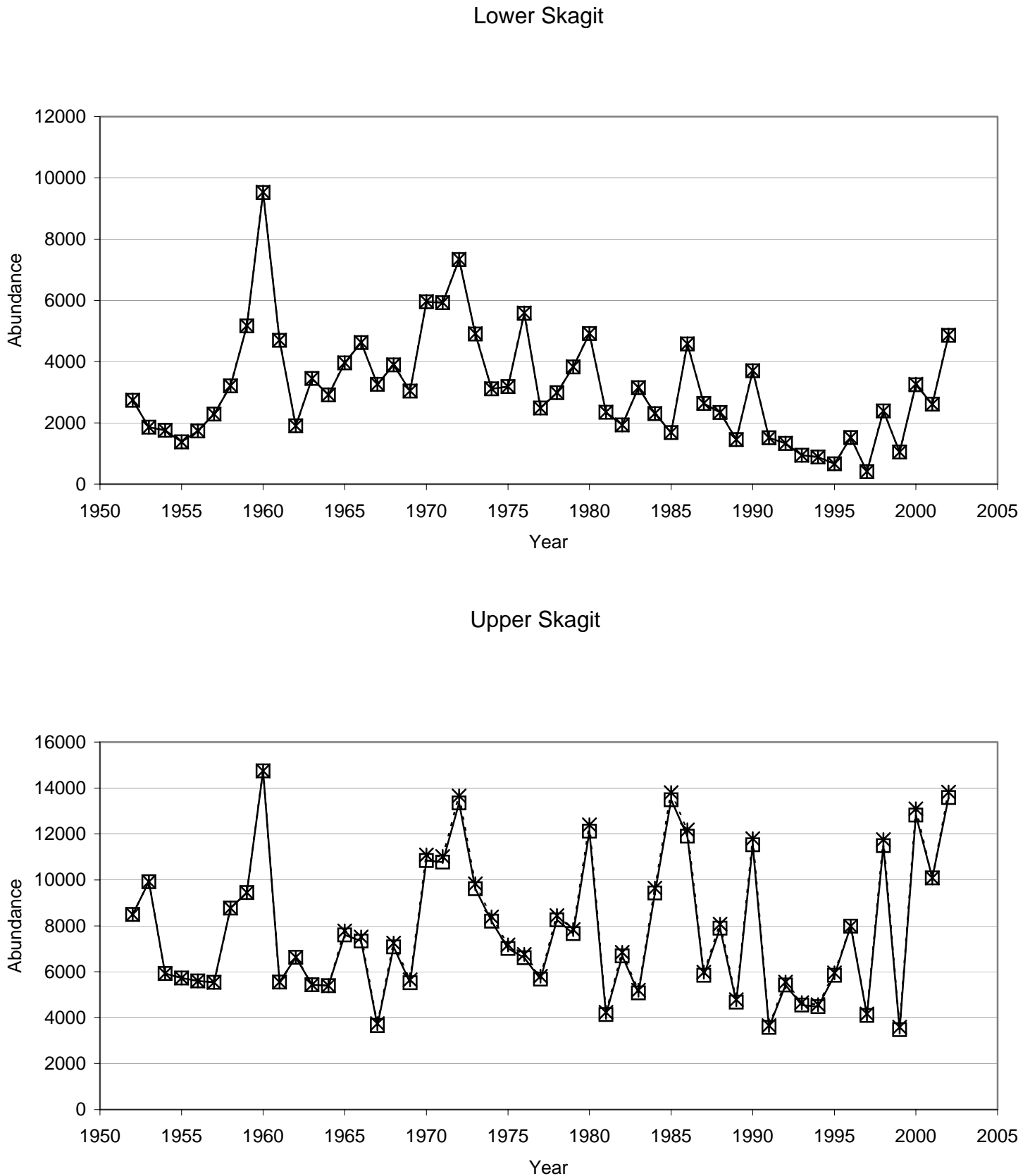
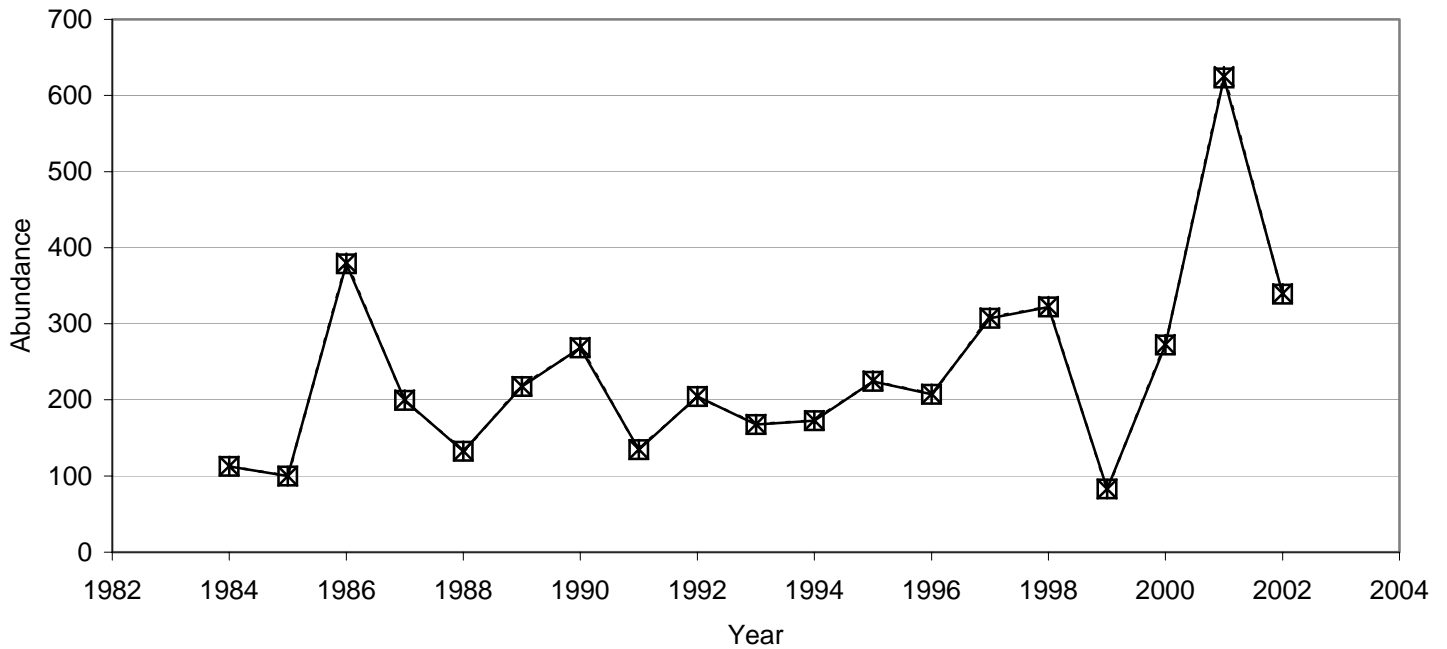


Figure A.2.4.1. Total and natural-origin spawner abundance estimates (cont.)

### Upper Cascade



### Lower Sauk

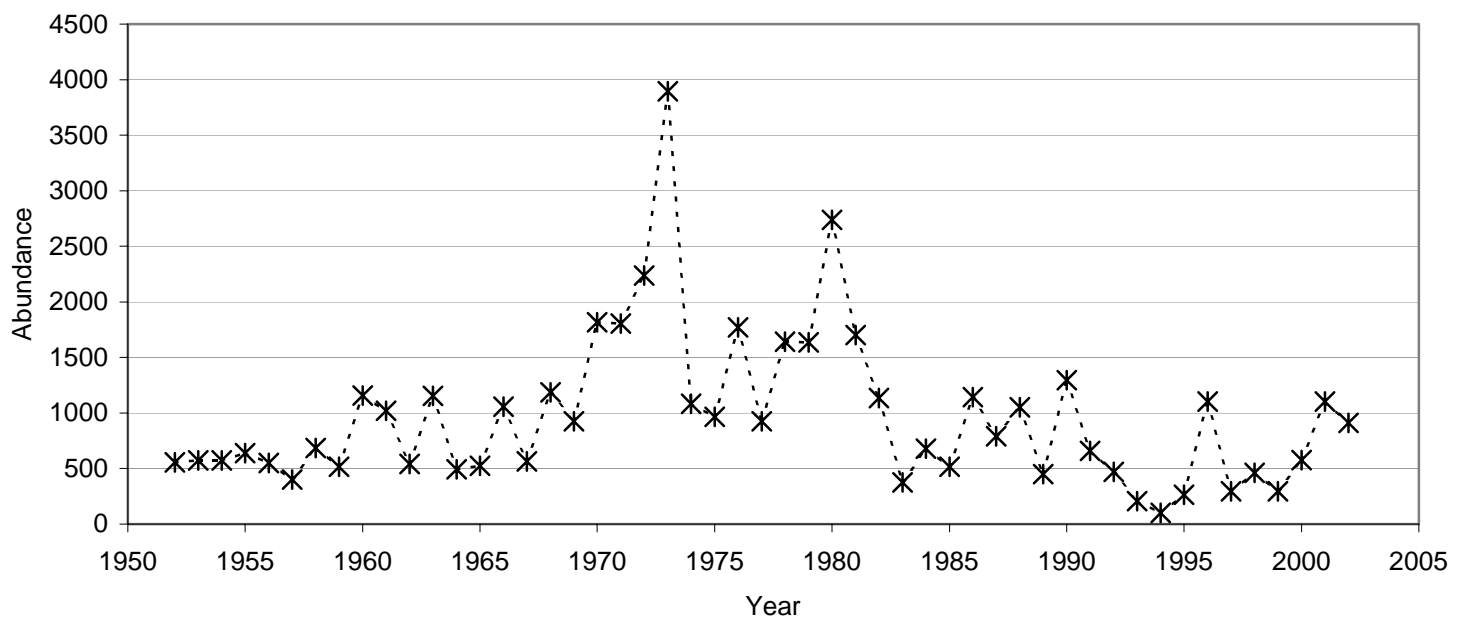
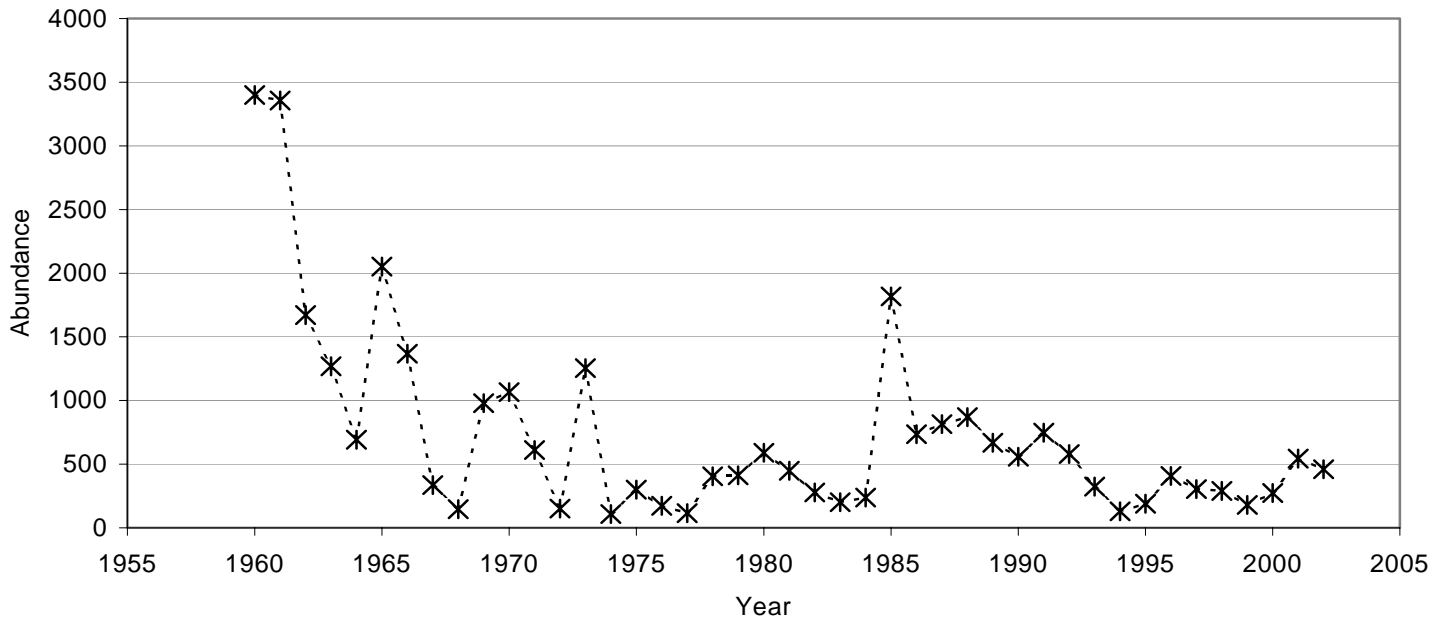


Figure A.2.4.1. Total and natural-origin spawner abundance estimates (cont.)

### Upper Sauk



### Suiattle

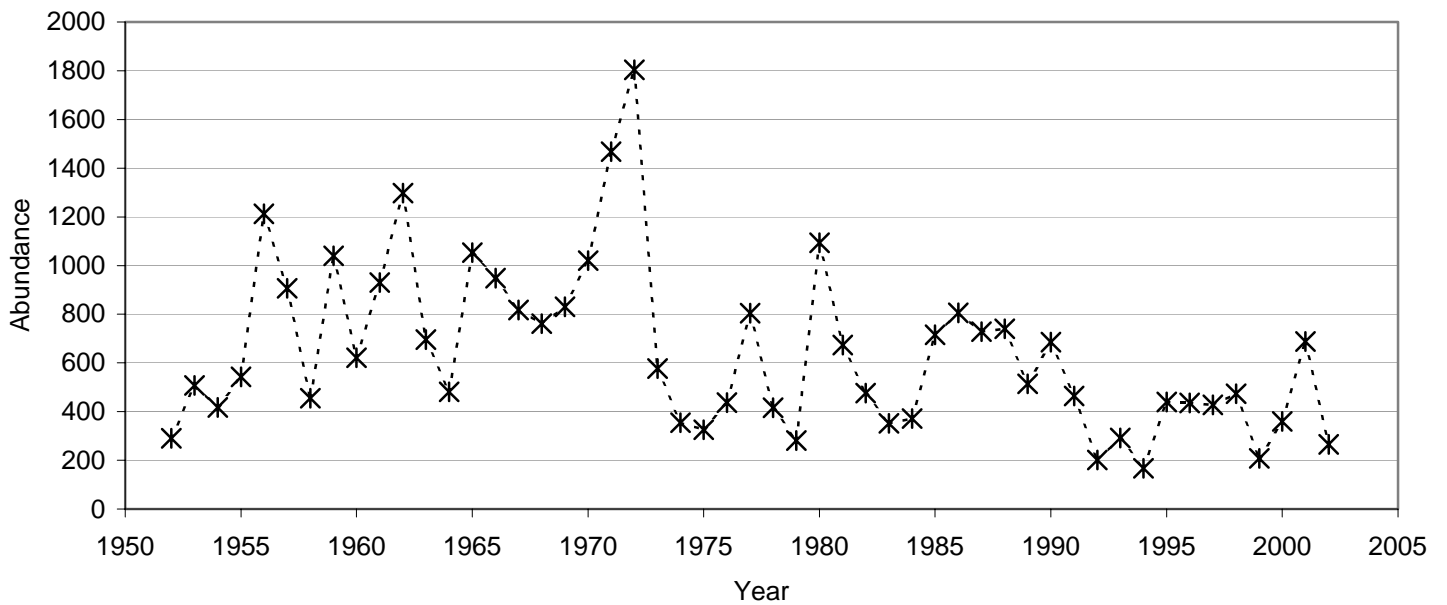
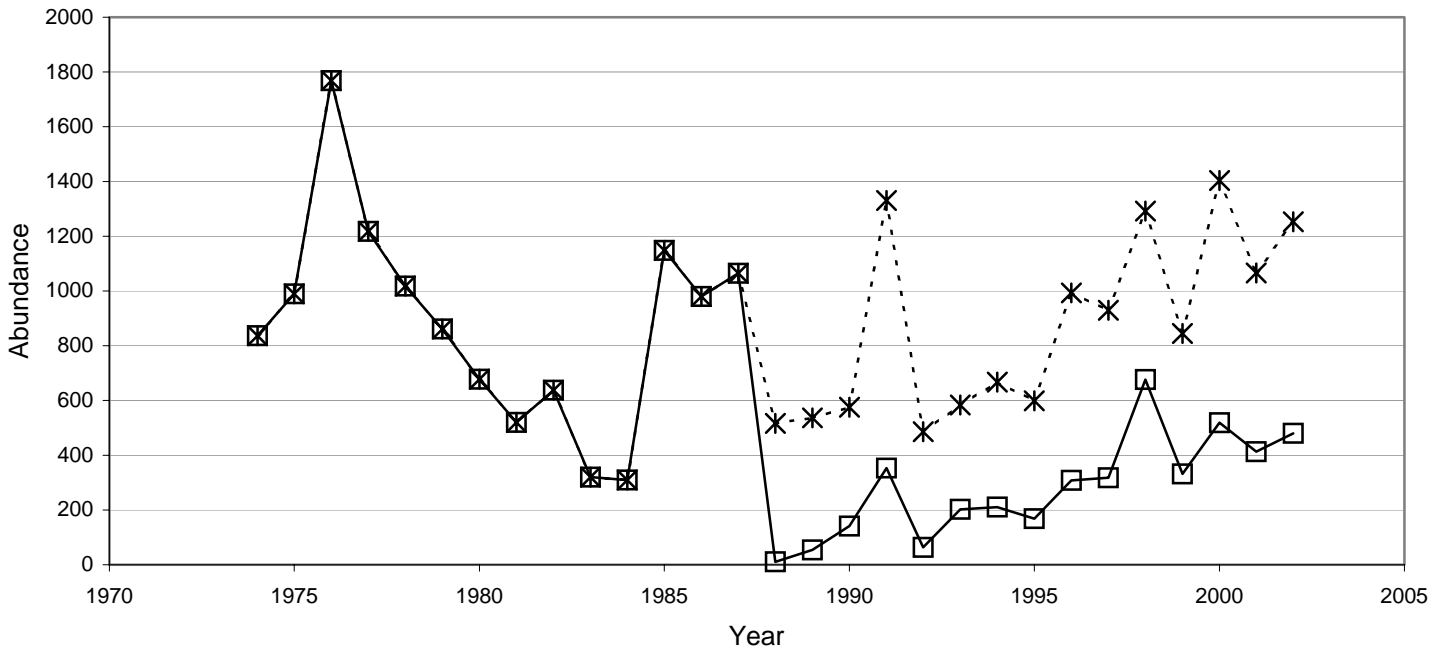


Figure A.2.4.1. Total and natural-origin spawner abundance estimates (cont.)

### North Fork Stillaguamish



### South Fork Stillaguamish

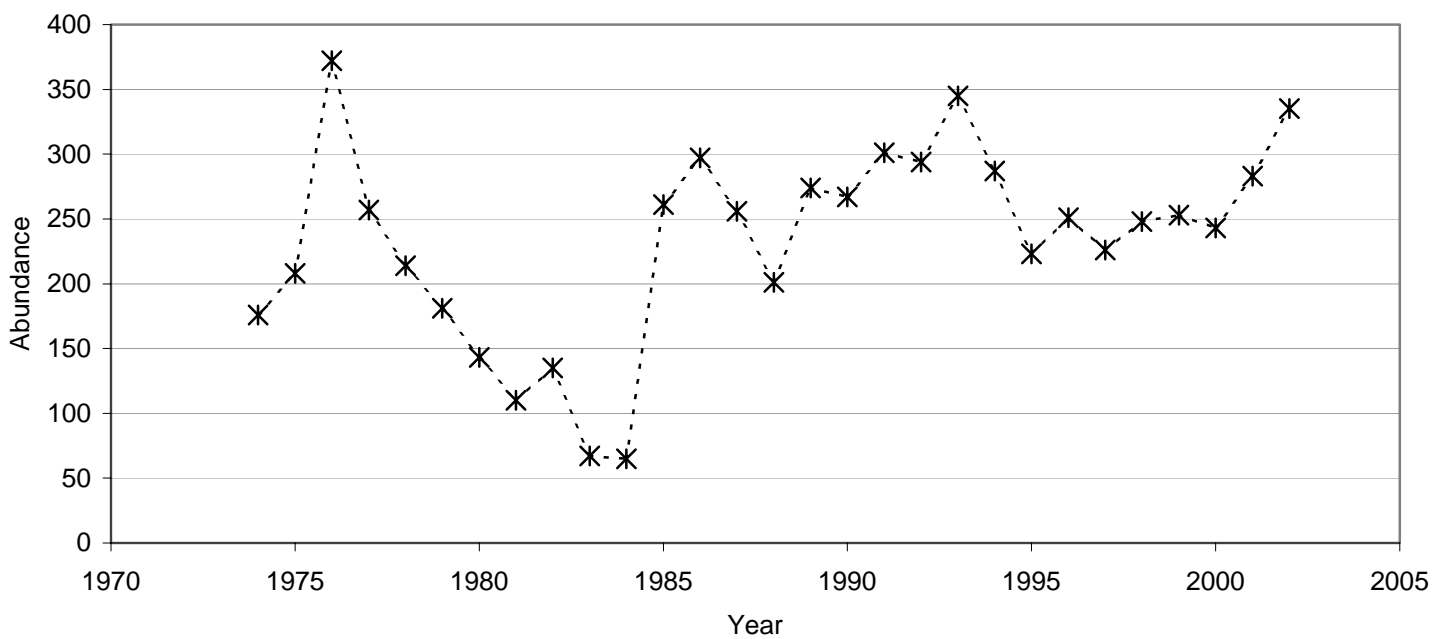
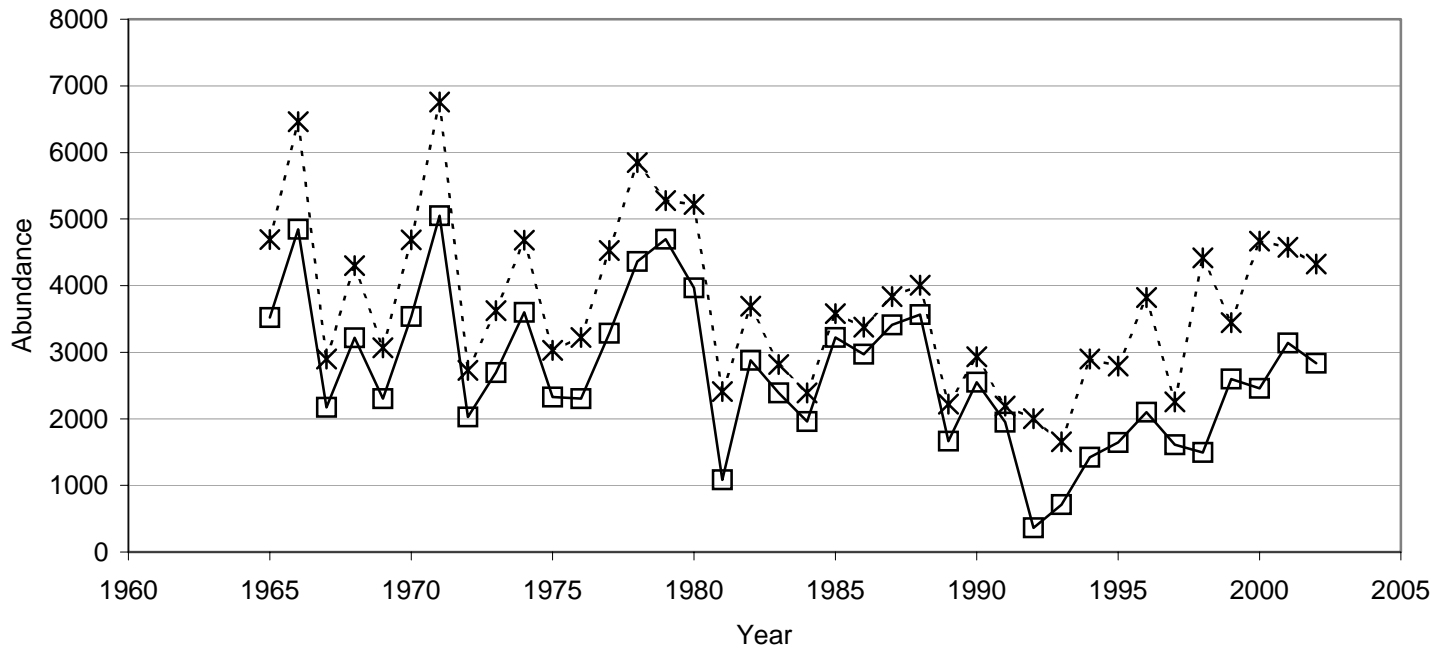


Figure A.2.4.1. Total and natural-origin spawner abundance estimates (cont.)

### Skykomish



### Snoqualmie

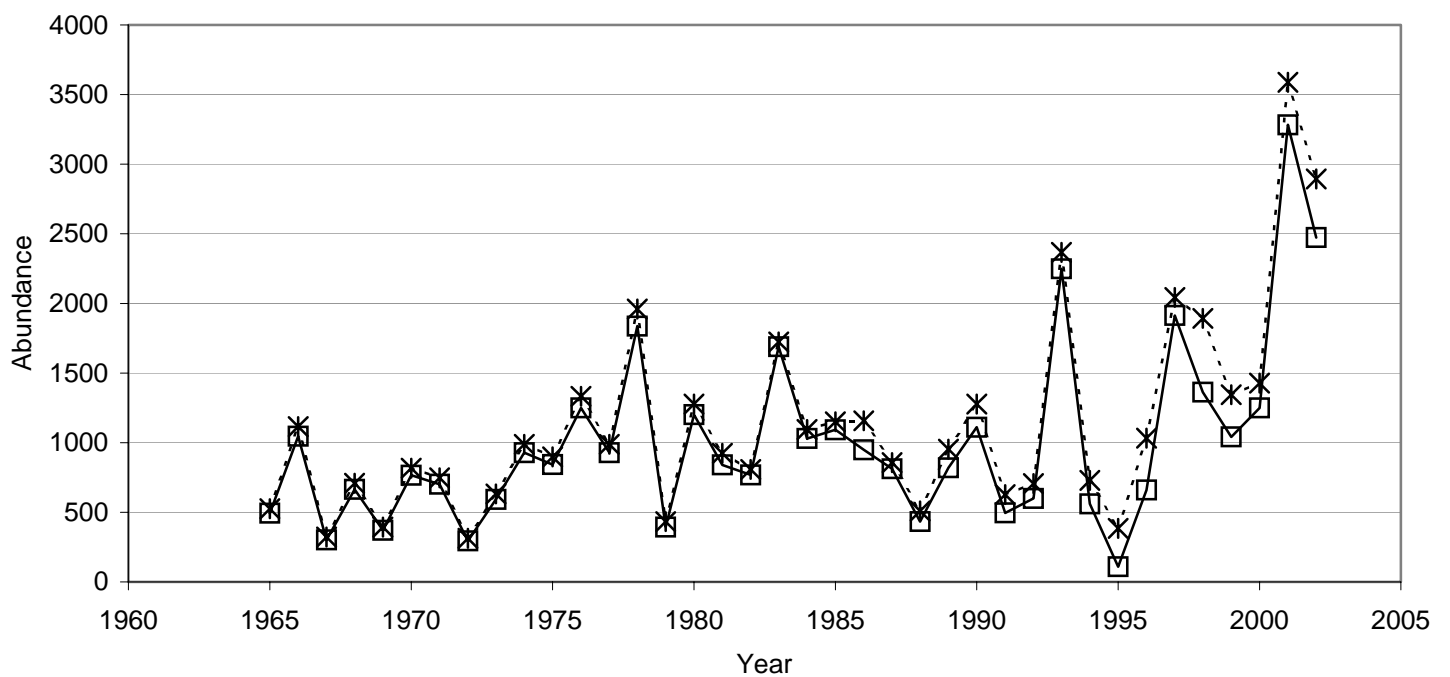
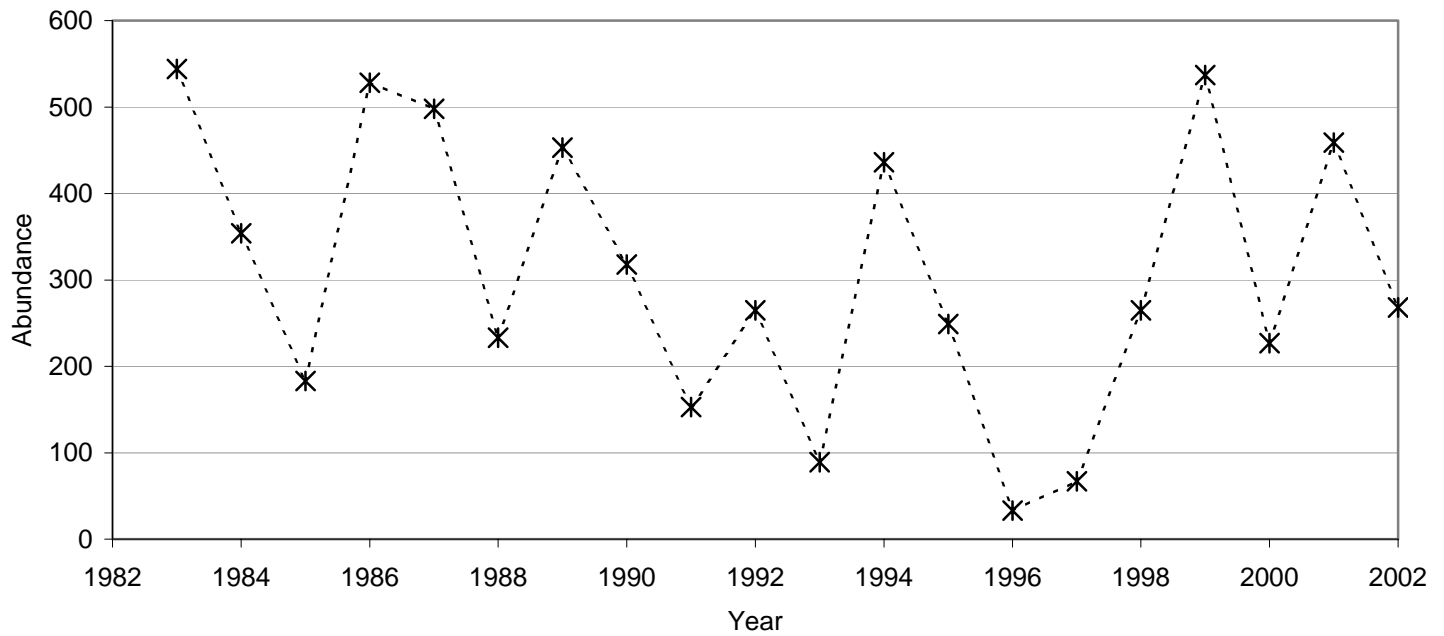


Figure A.2.4.1. Total and natural-origin spawner abundance estimates (cont.)

North Lake Washington tributaries



Cedar

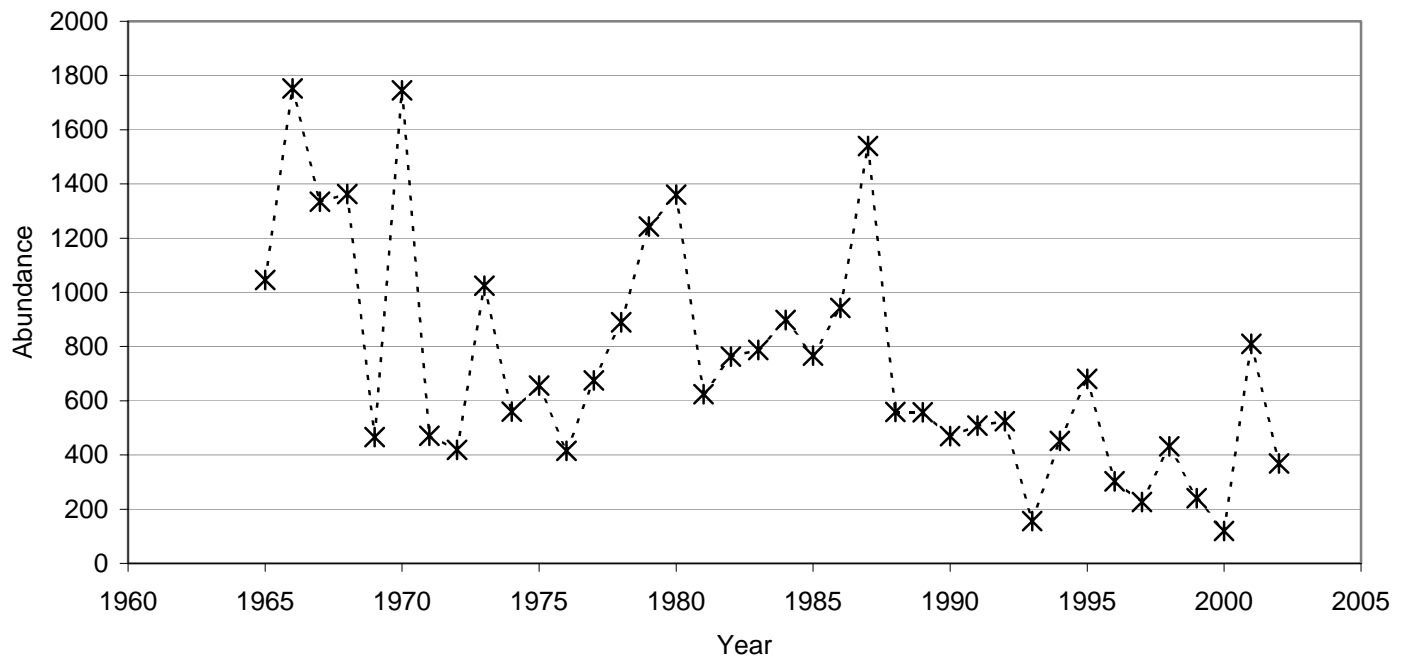
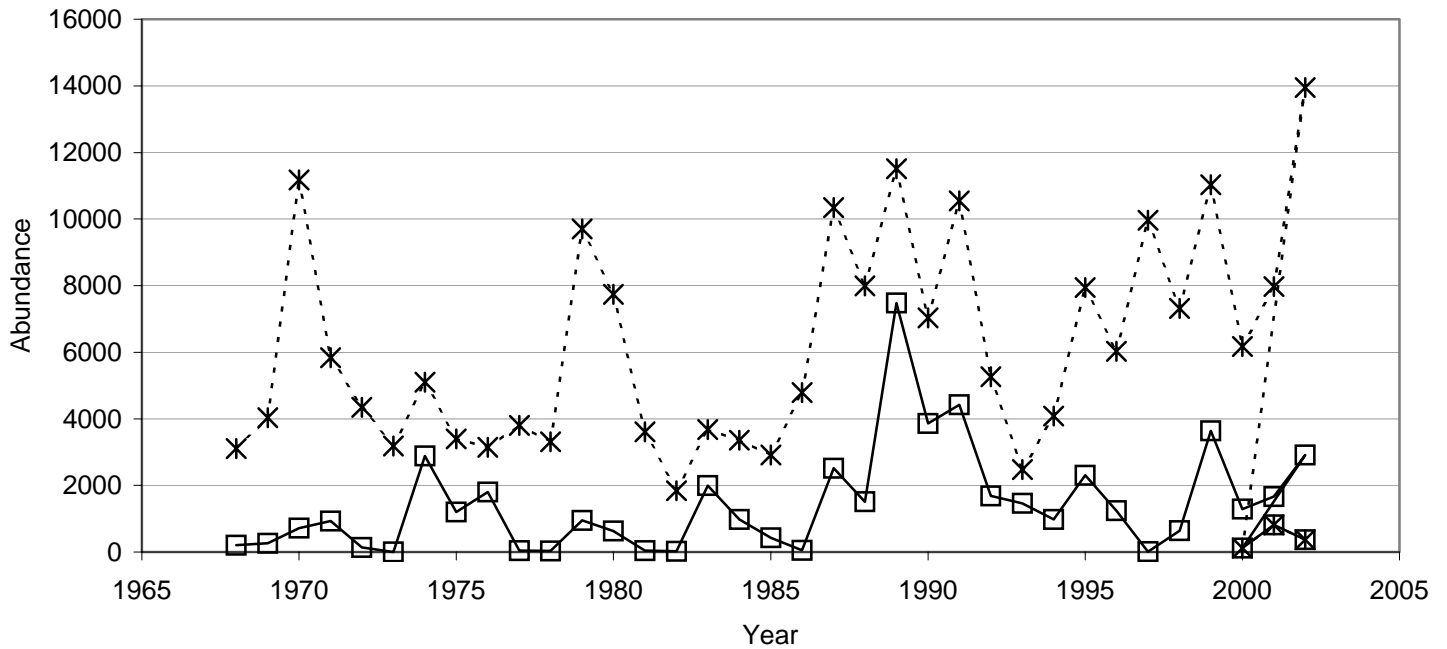


Figure A.2.4.1. Total and natural-origin spawner abundance estimates (cont.)

Green/Duwamish



Puyallup

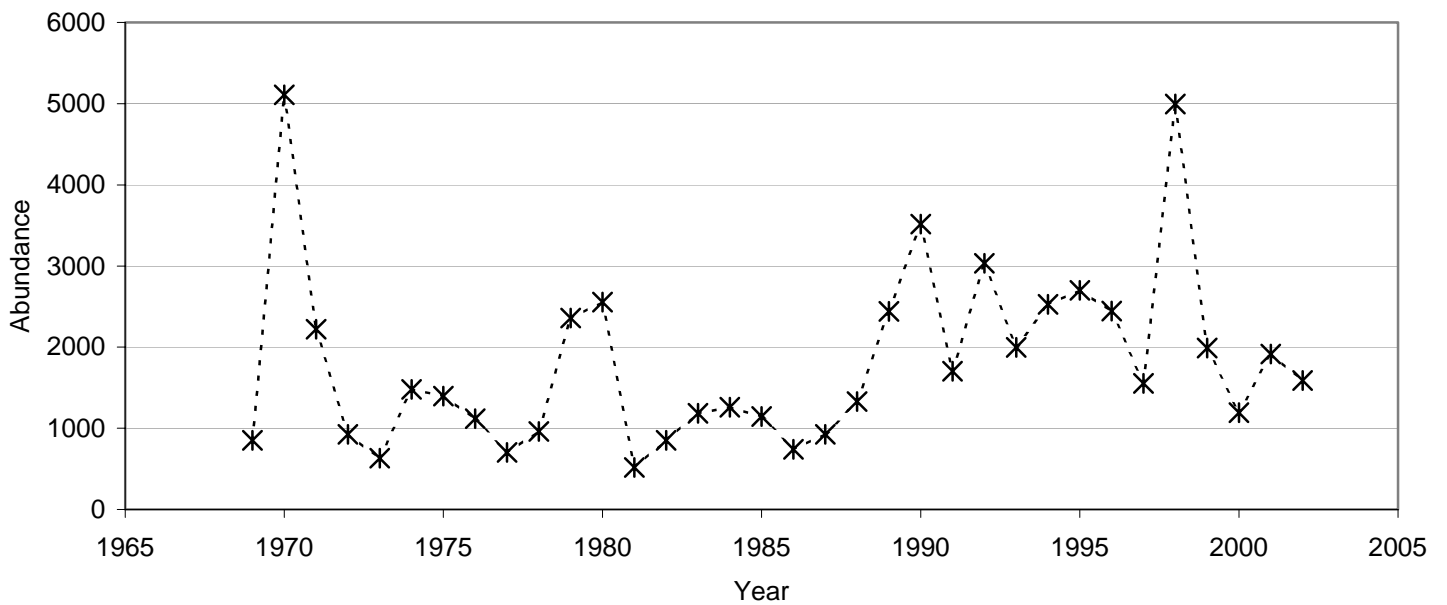
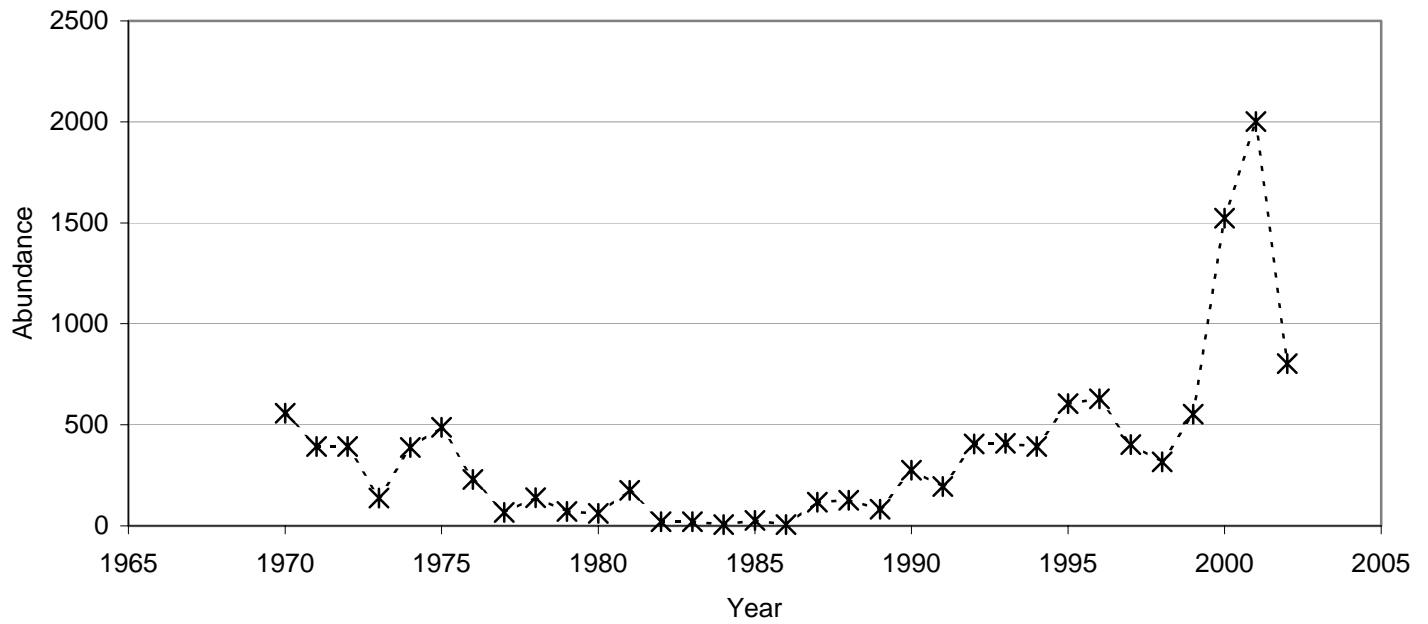


Figure A.2.4.1. Total and natural-origin spawner abundance estimates (cont.)

### White



### Nisqually

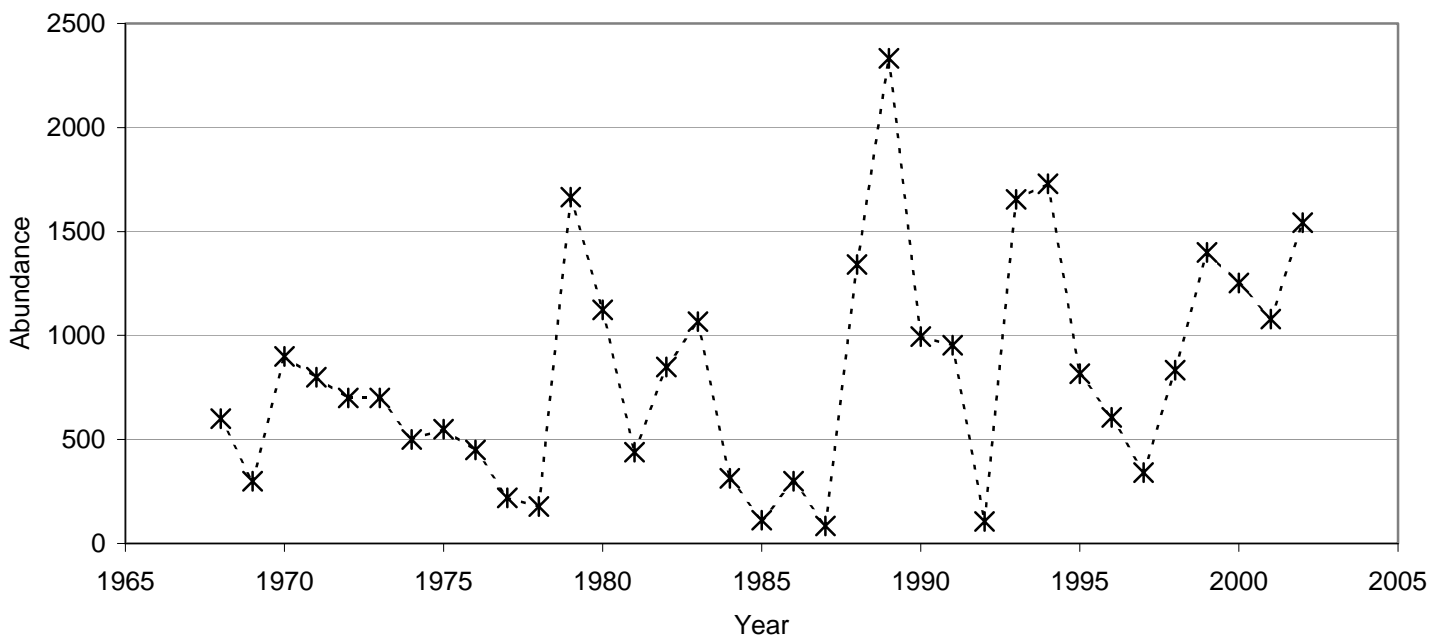
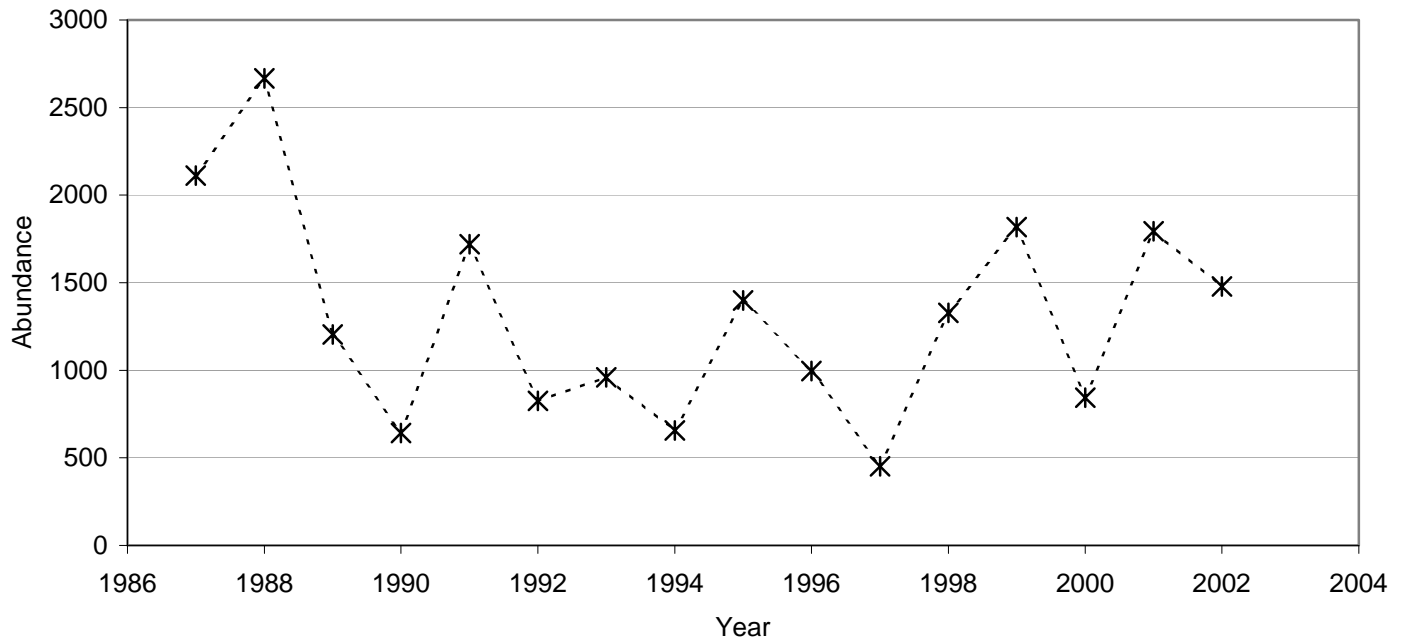




Figure A.2.4.1. Total and natural-origin spawner abundance estimates (cont.)  
Skokomish



Dosewallips/Hamma Hamma/Duckabush

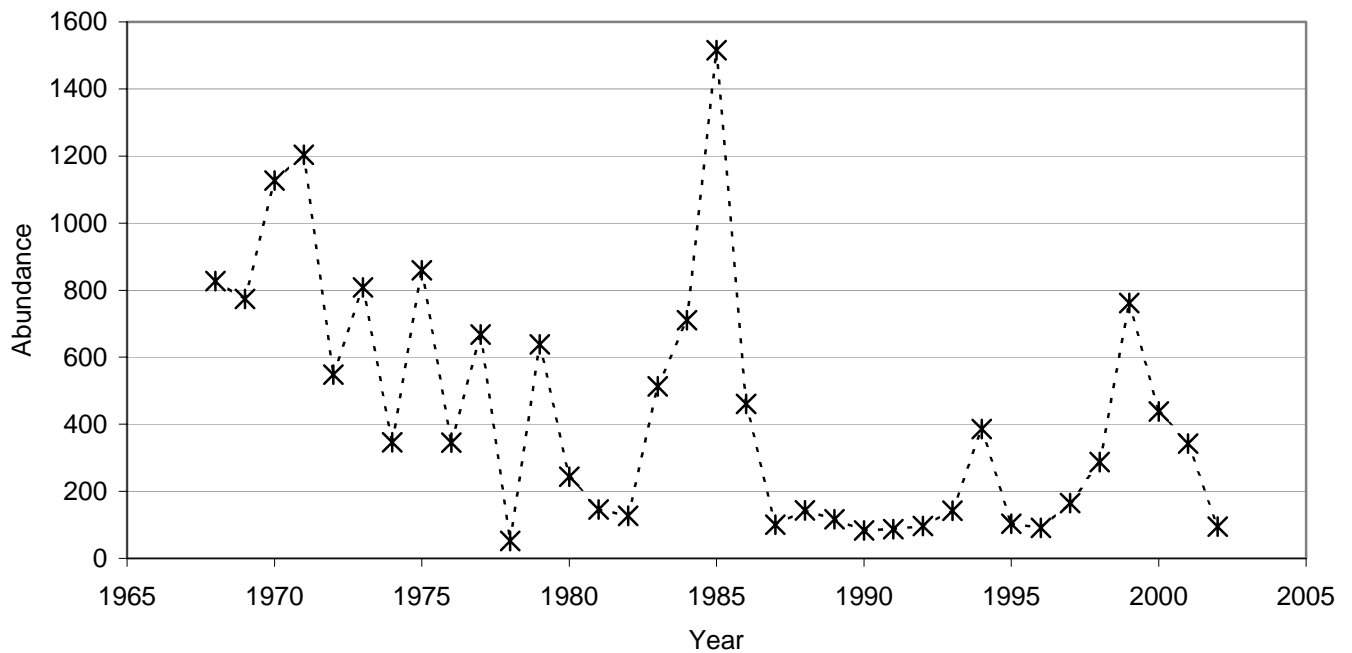
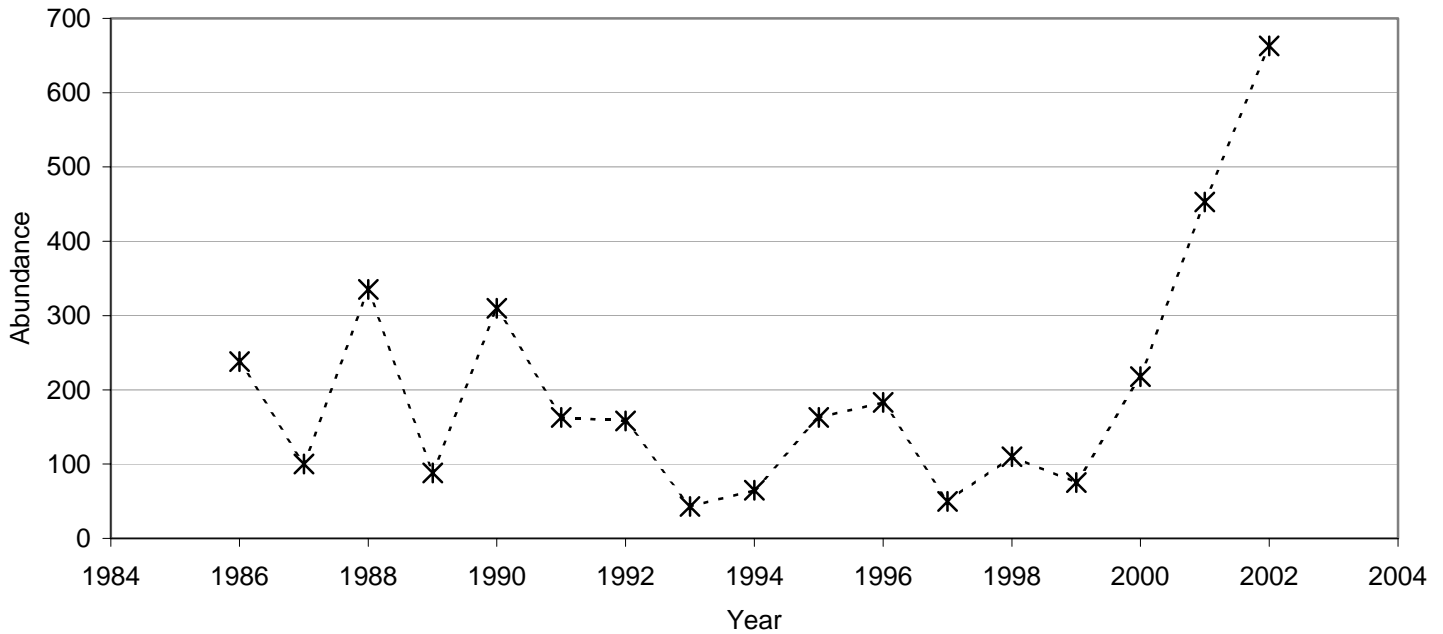


Figure A.2.4.1. Total and natural-origin spawner abundance estimates (cont.)

### Dungeness



### Elwha

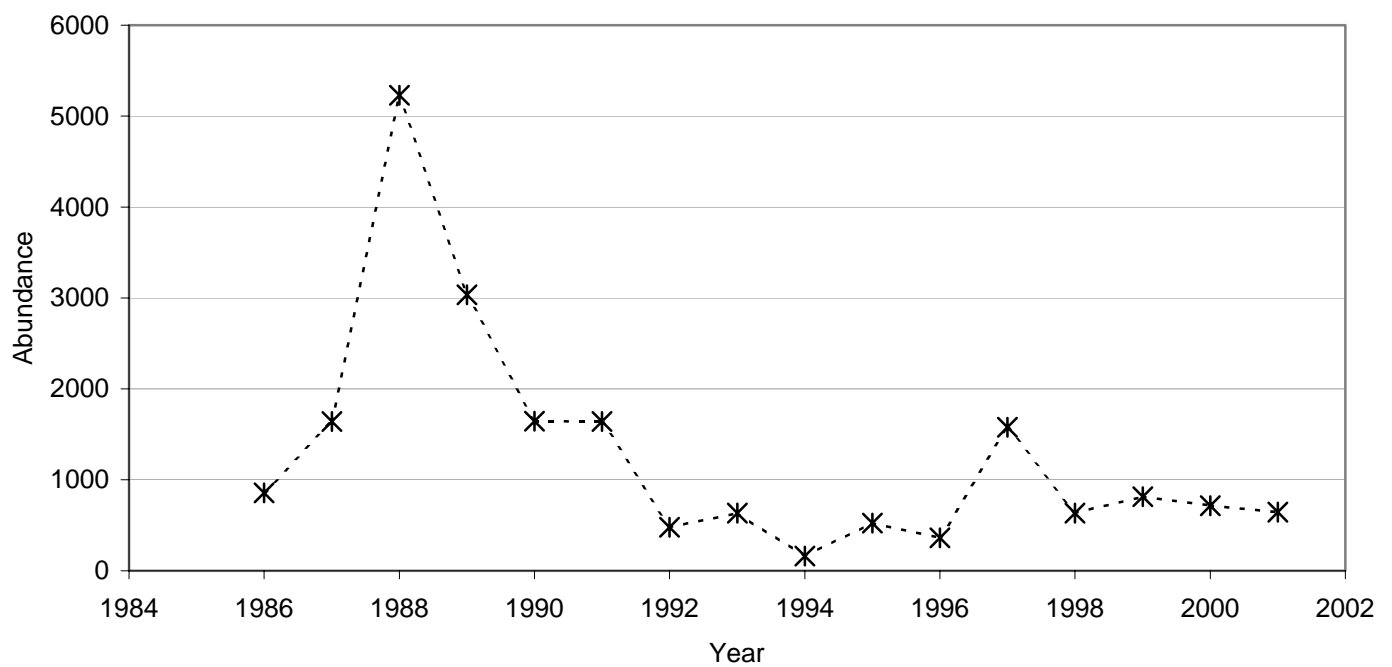


Figure A.2.4.2. Puget Sound Chinook pre-harvest recruits and spawners vs. brood year by population

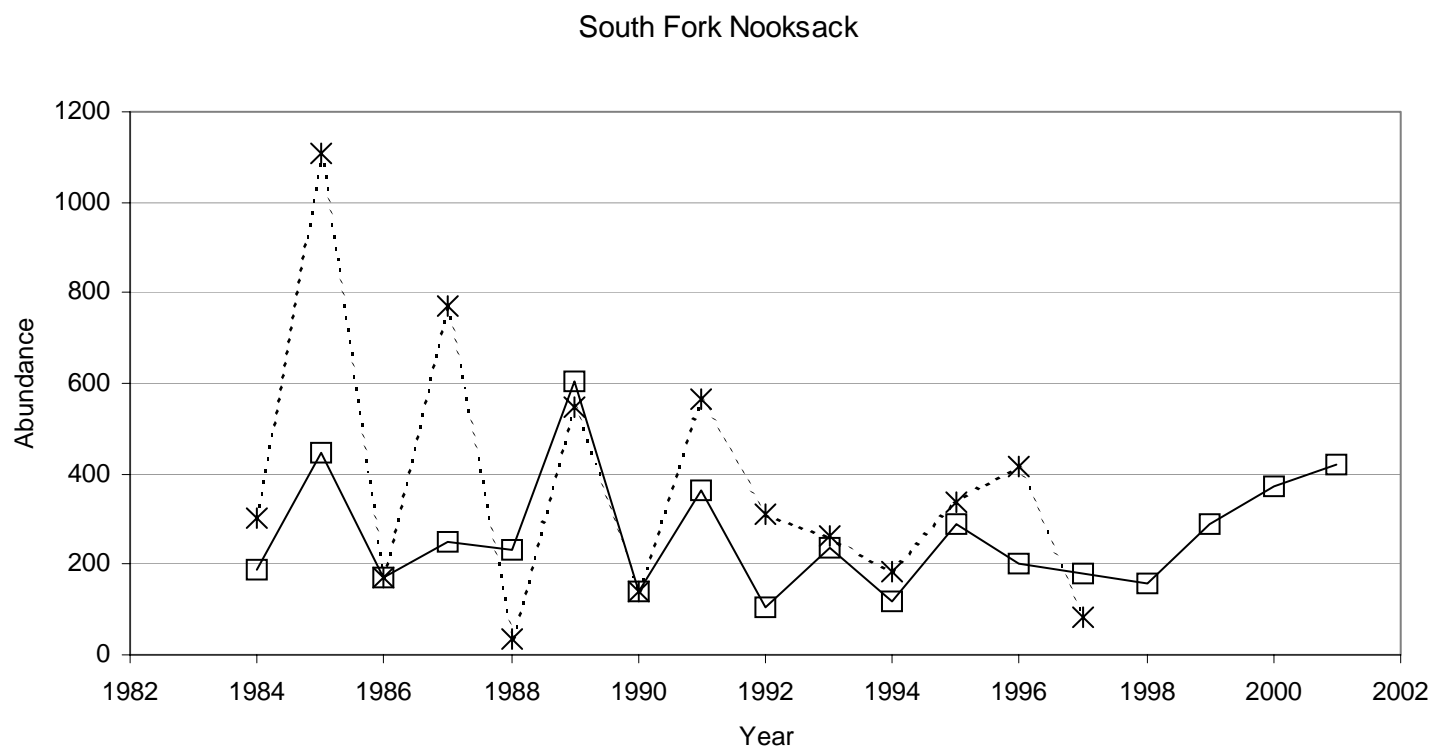
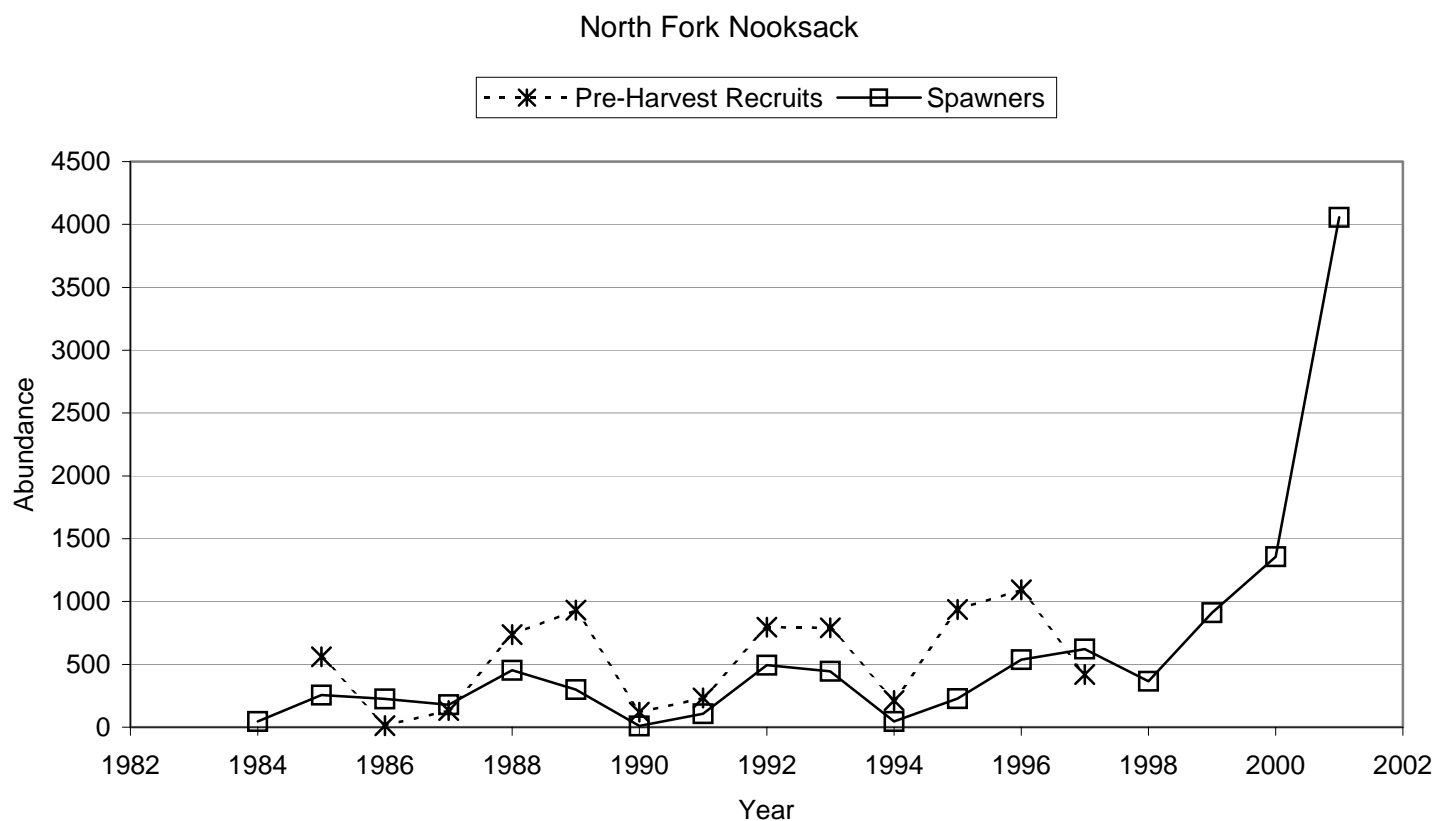
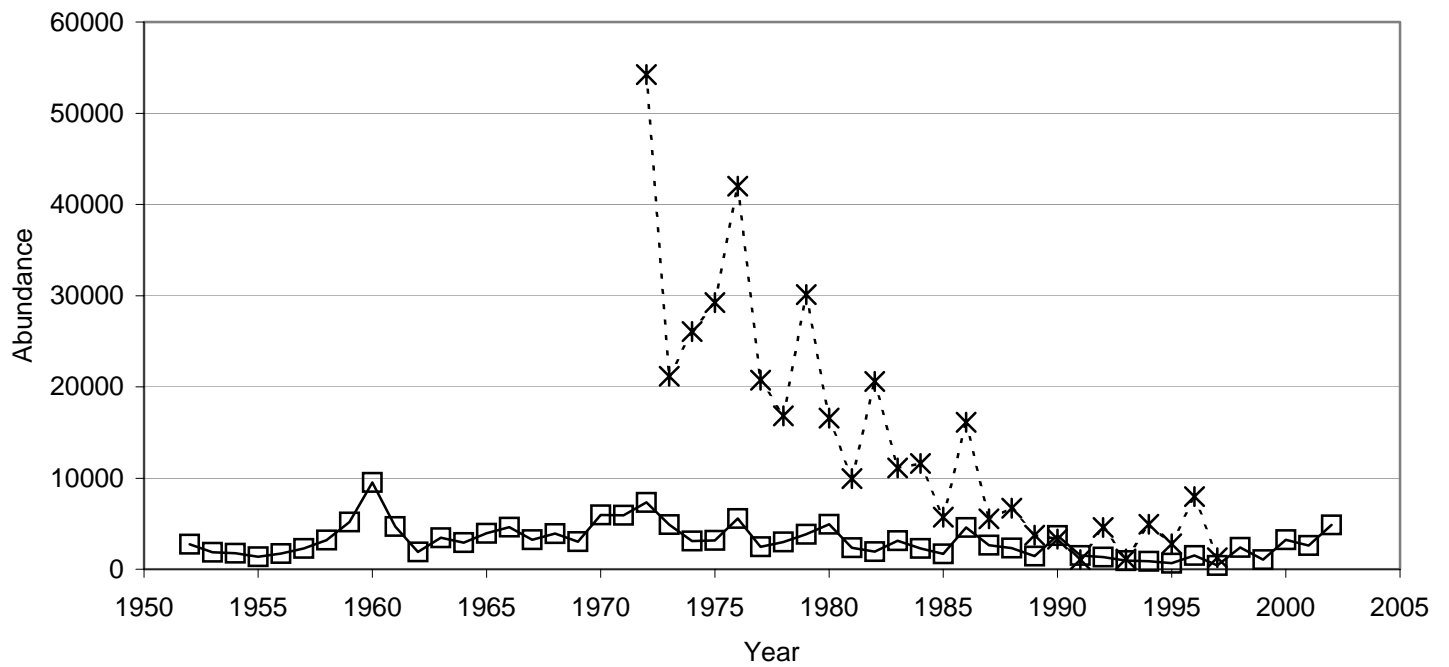


Figure A.2.4.2 Puget Sound Chinook pre-harvest recruits and spawners (cont.)

Lower Skagit



Upper Skagit

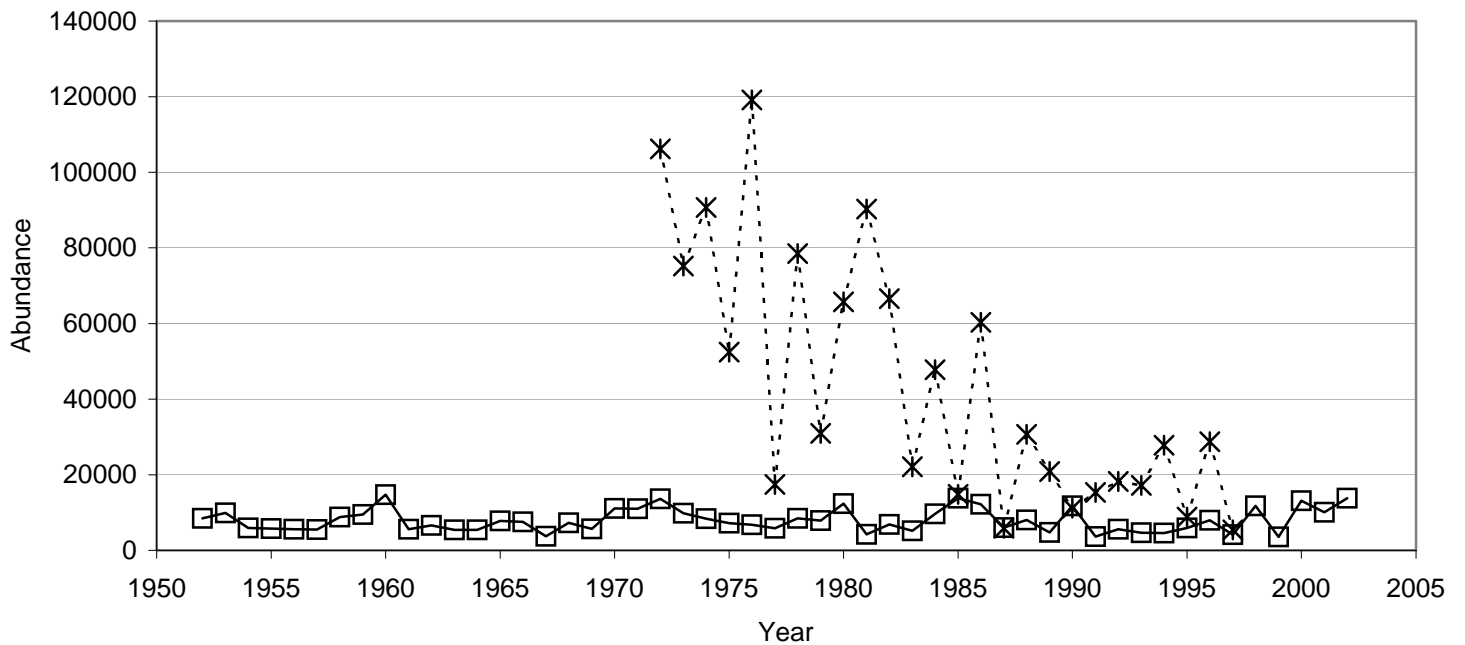
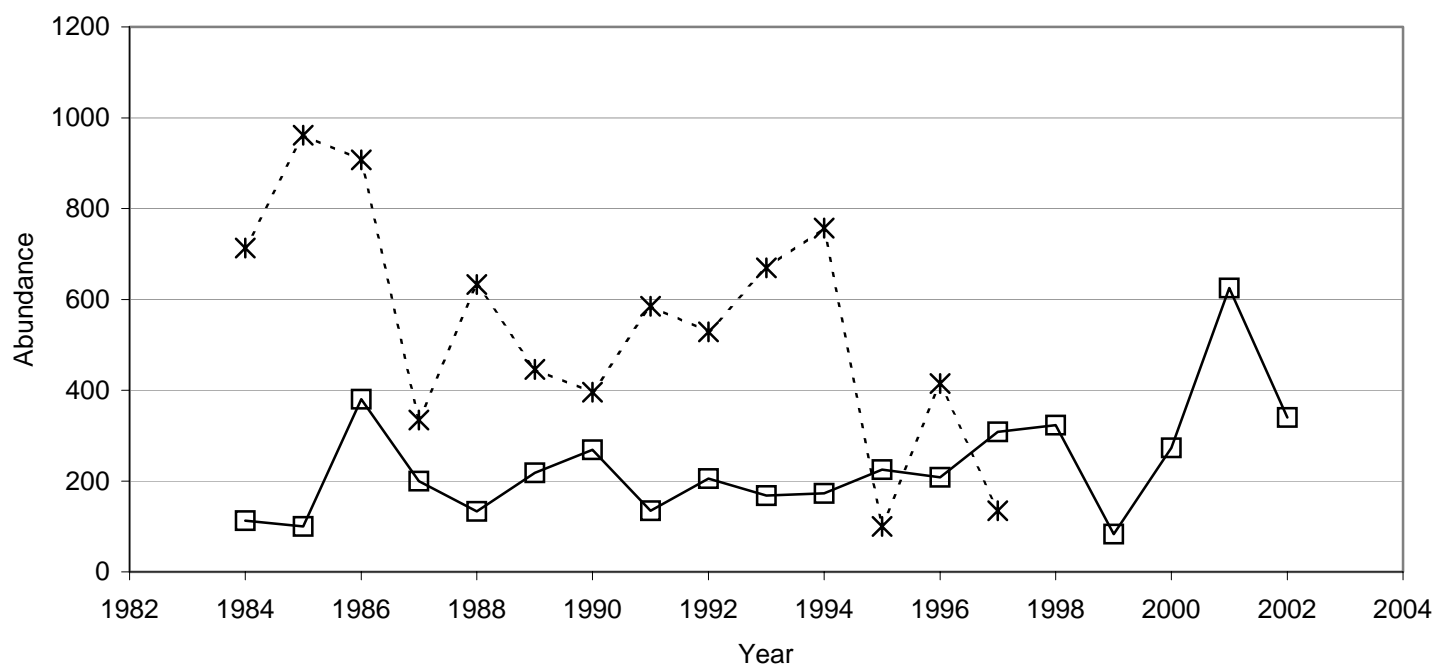


Figure A.2.4.2 Puget Sound Chinook pre-harvest recruits and spawners (cont.)

### Upper Cascade



### Lower Sauk

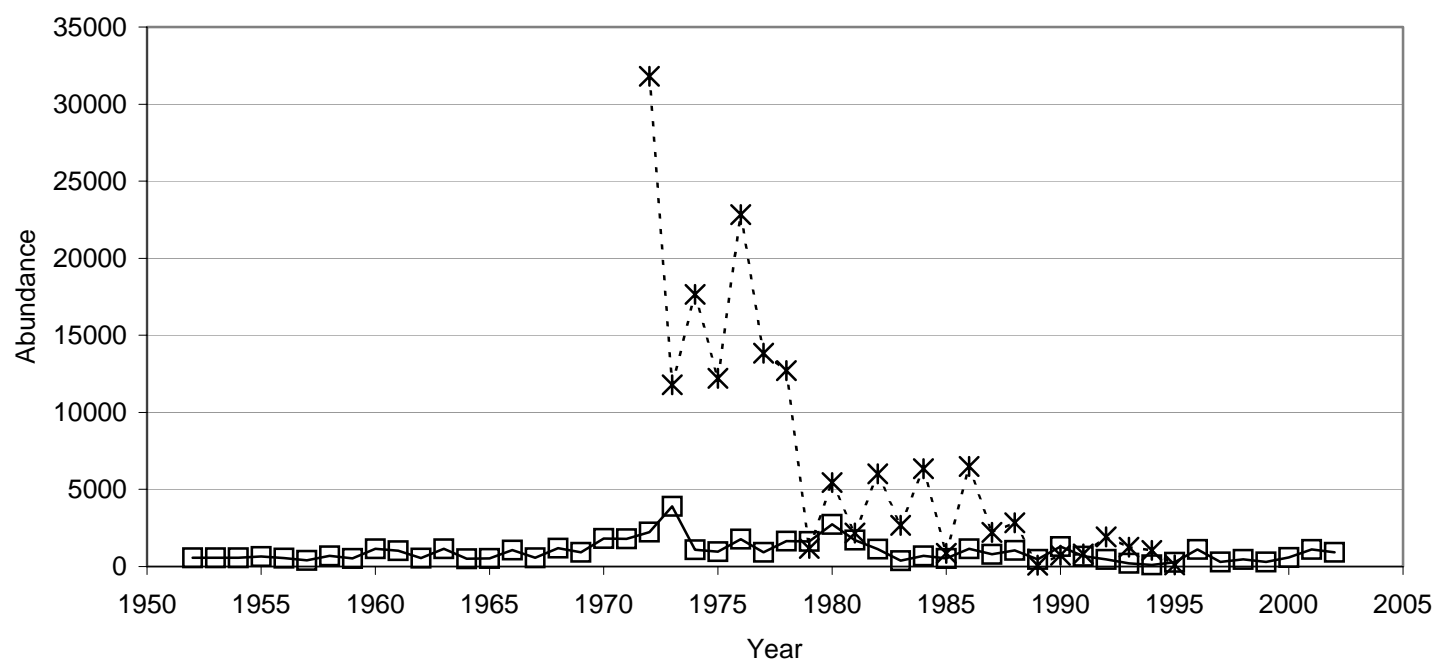
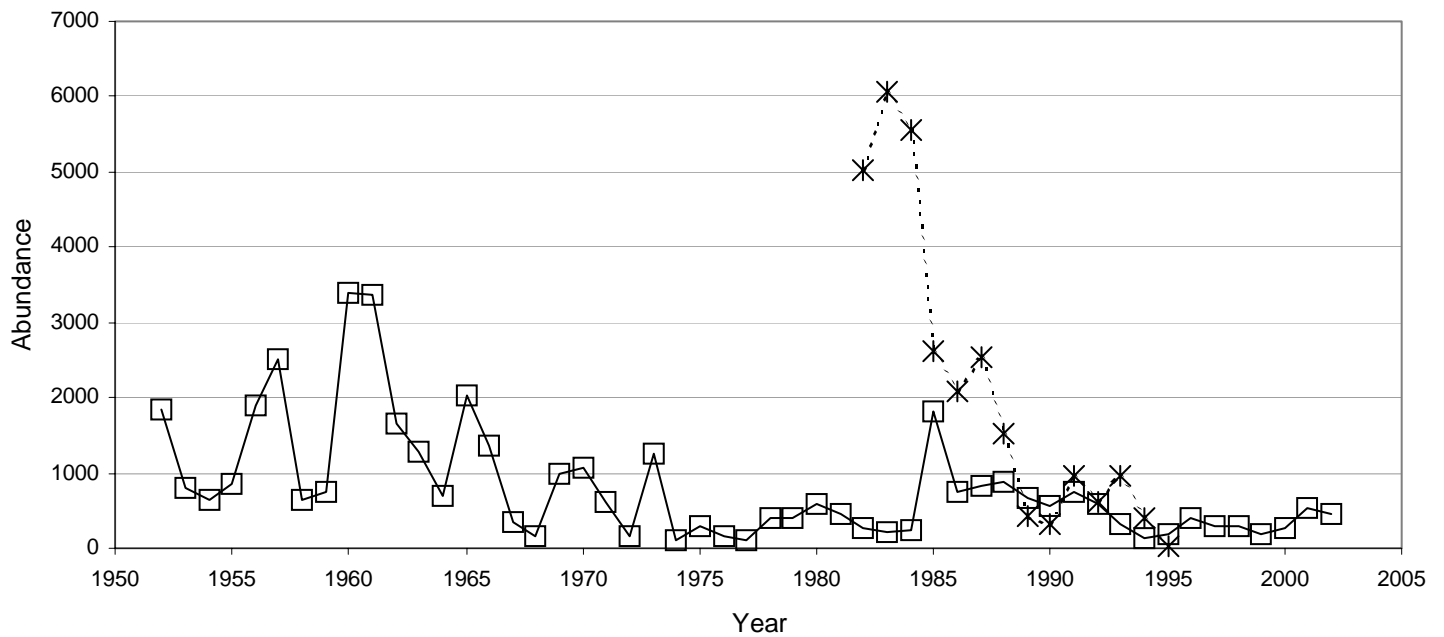


Figure A.2.4.2 Puget Sound Chinook pre-harvest recruits and spawners (cont.)

### Upper Sauk



### Suiattle

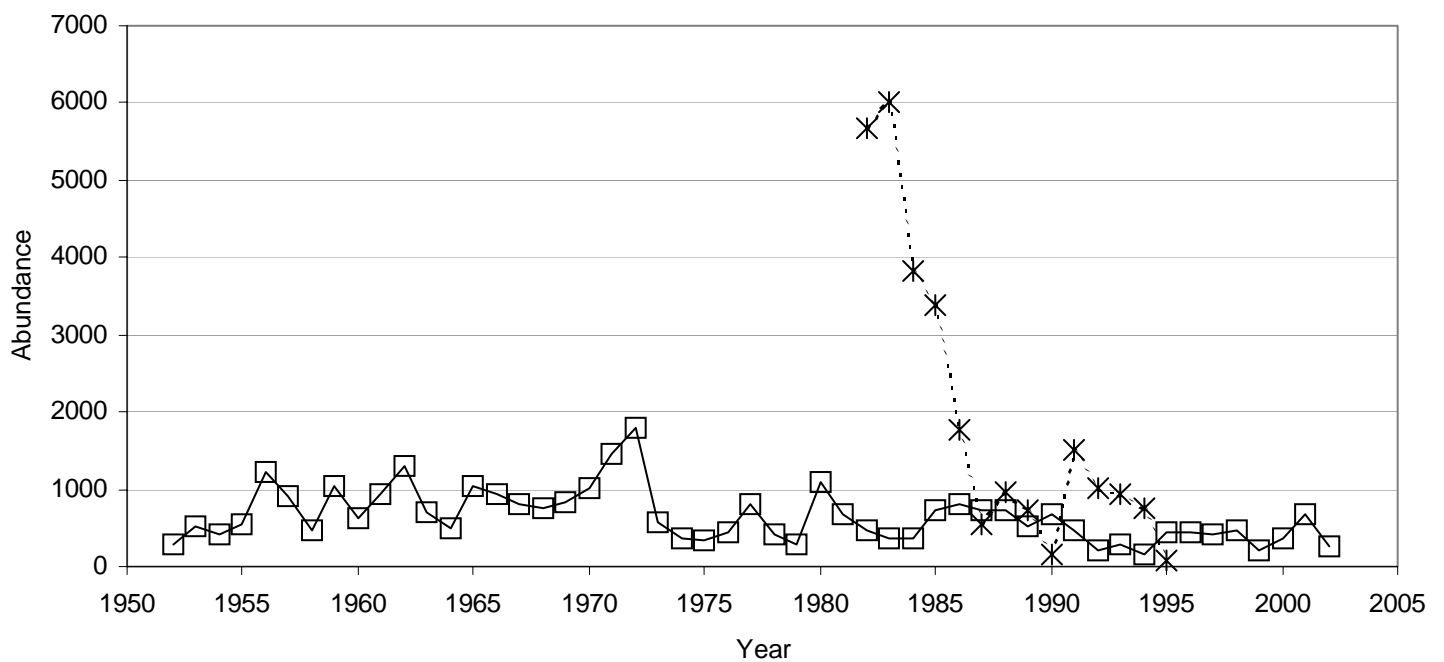
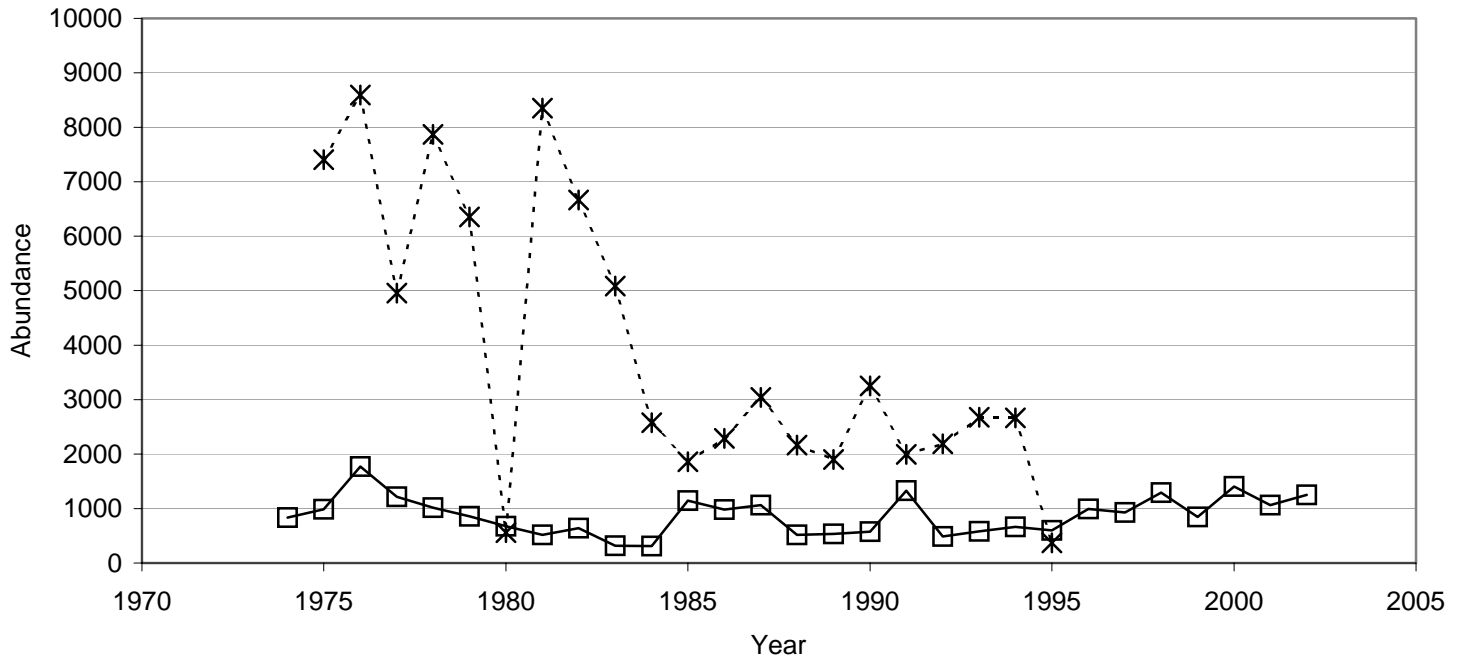


Figure A.2.4.2 Puget Sound Chinook pre-harvest recruits and spawners (cont.)

North Fork Stilliguamish



South Fork Stilliguamish

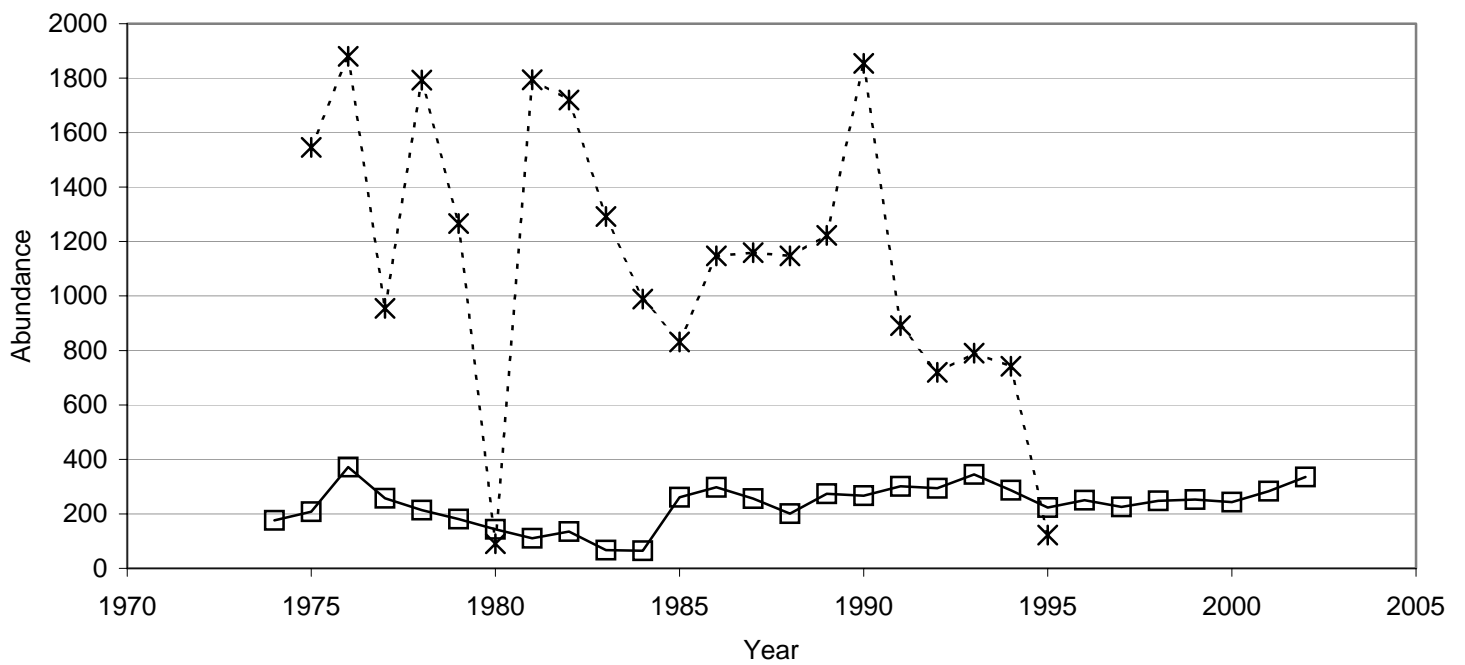
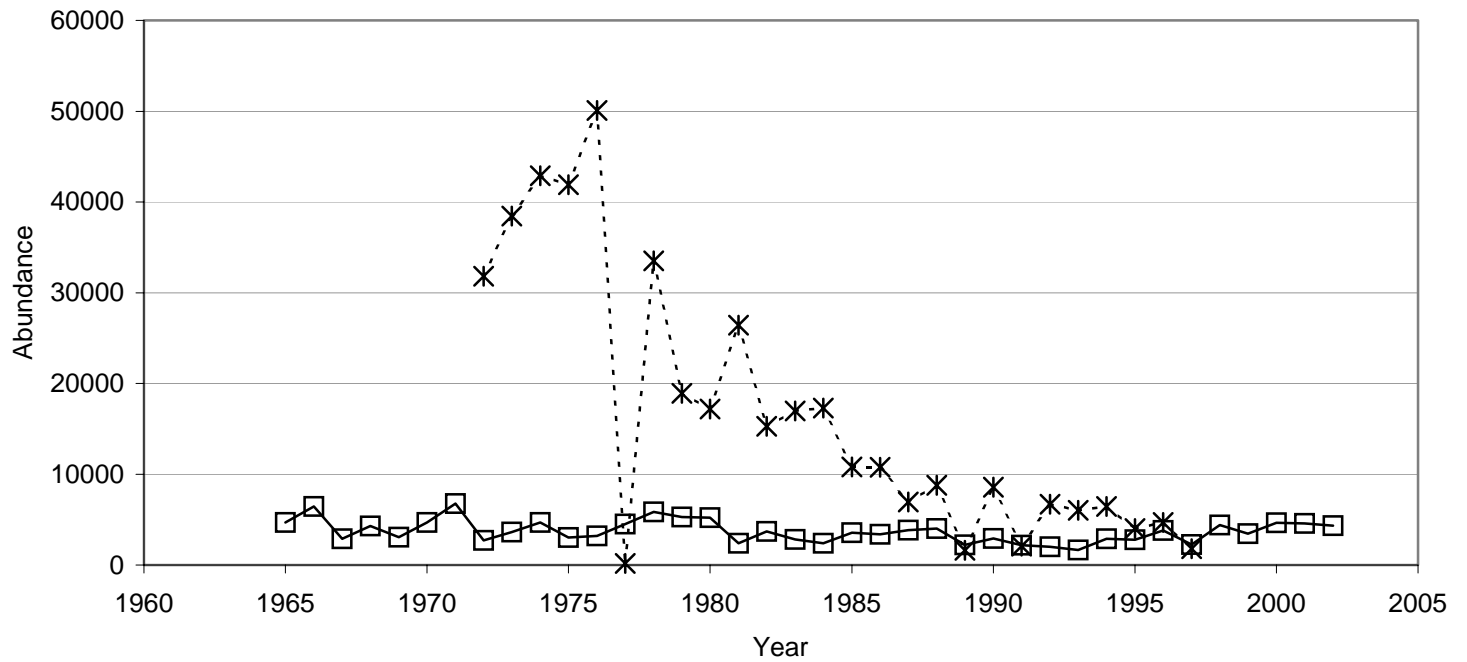


Figure A.2.4.2 Puget Sound Chinook pre-harvest recruits and spawners (cont.)

Skykomish



Snoqualmie

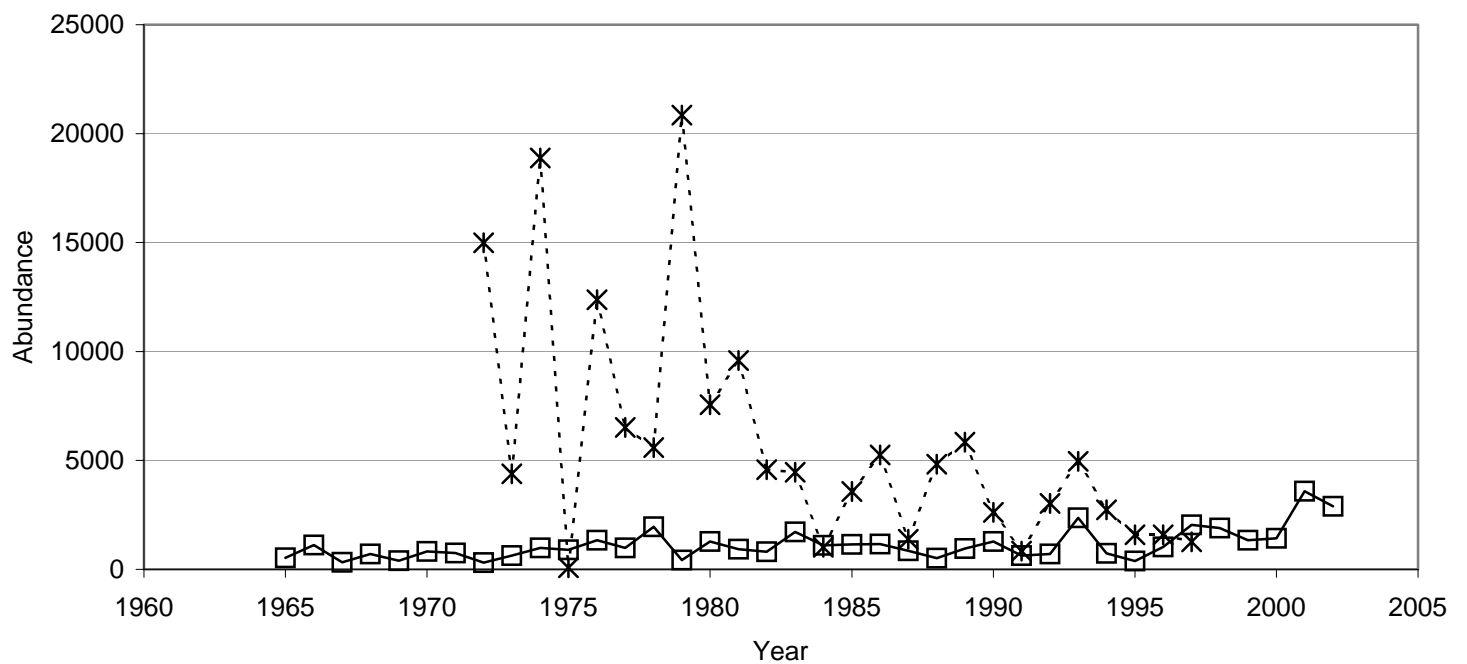
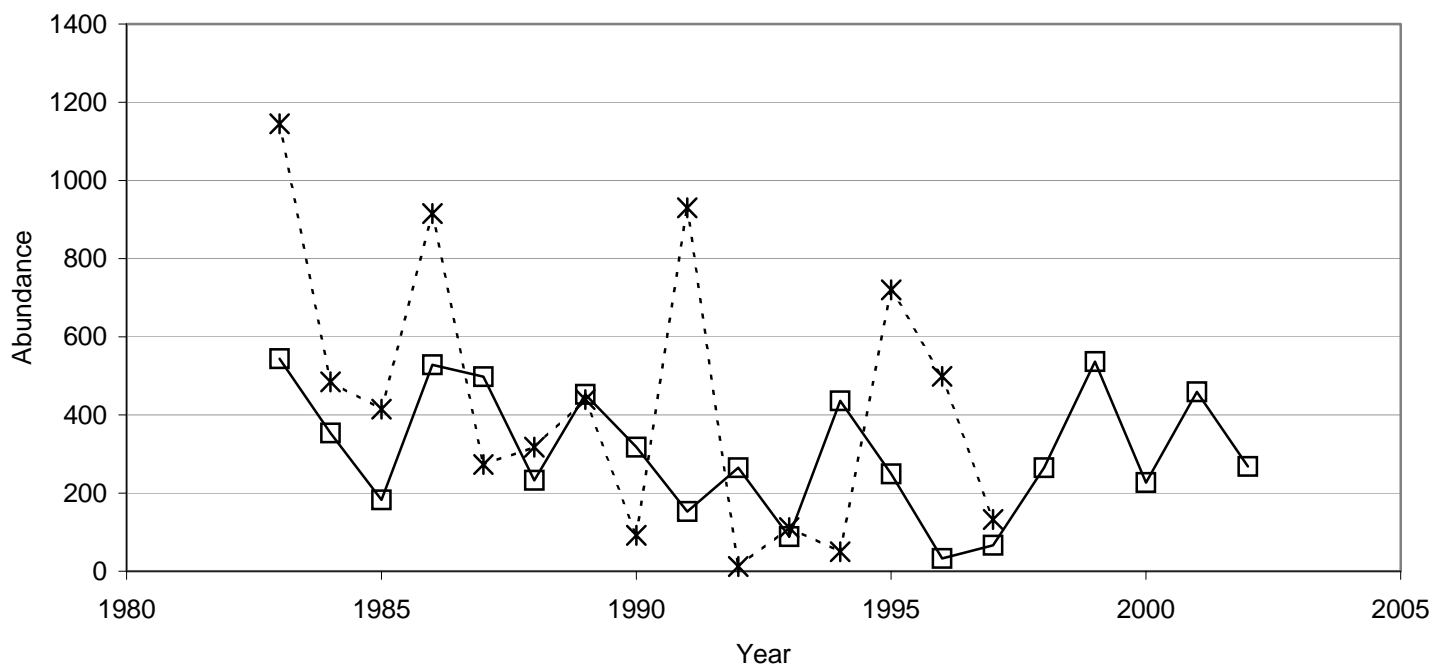




Figure A.2.4.2 Puget Sound Chinook pre-harvest recruits and spawners (cont.)

North Lake Washington



Cedar

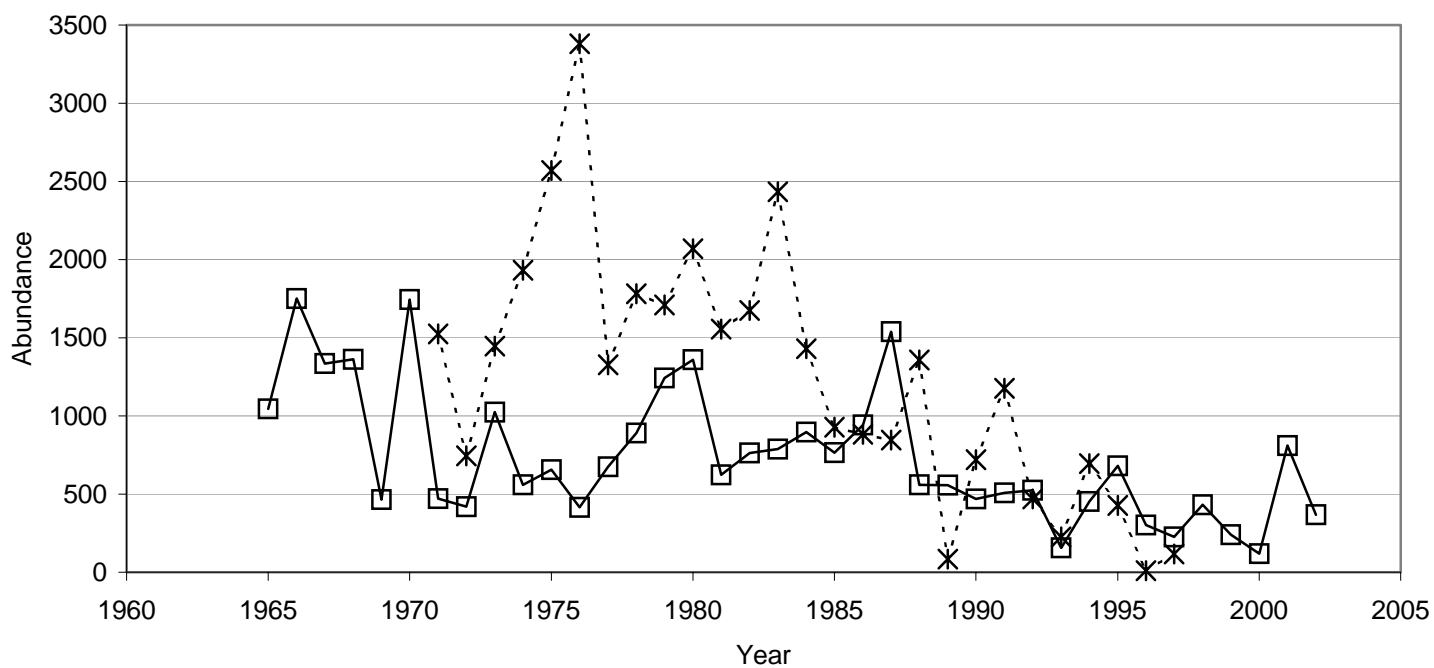
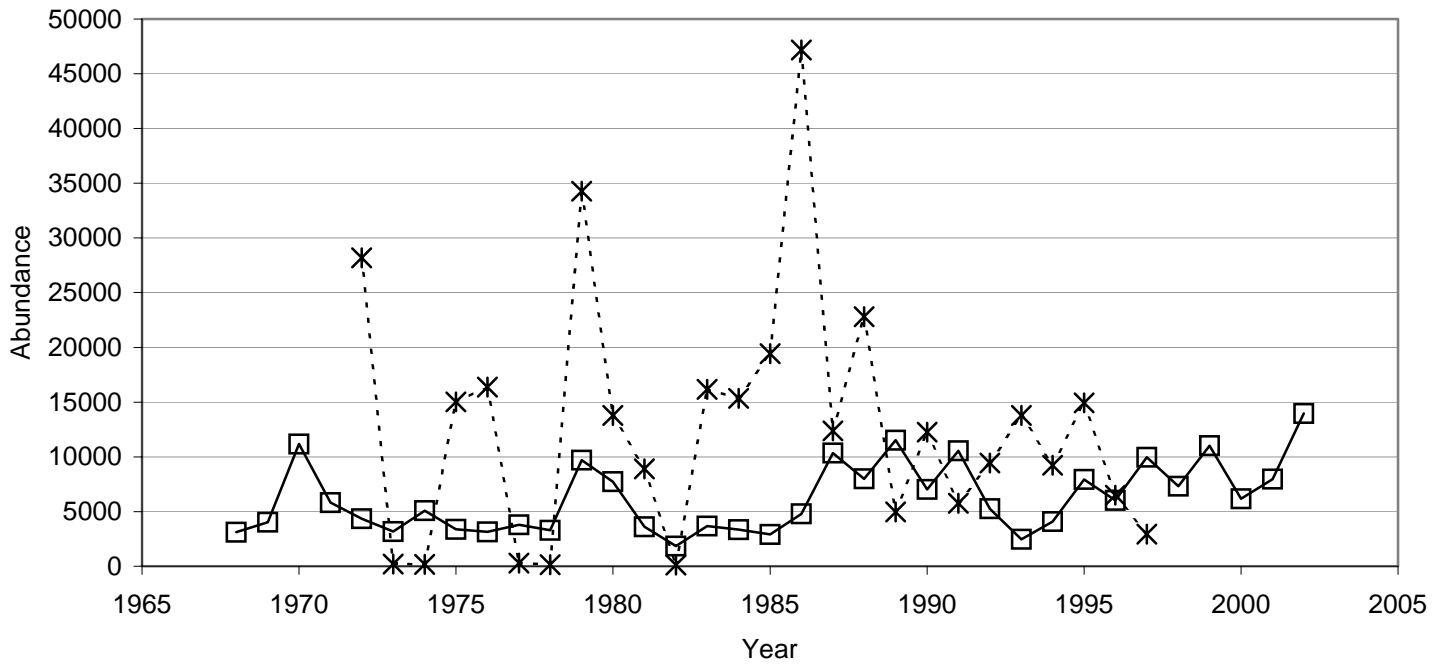


Figure A.2.4.2 Puget Sound Chinook pre-harvest recruits and spawners (cont.)

Green



Puyallup

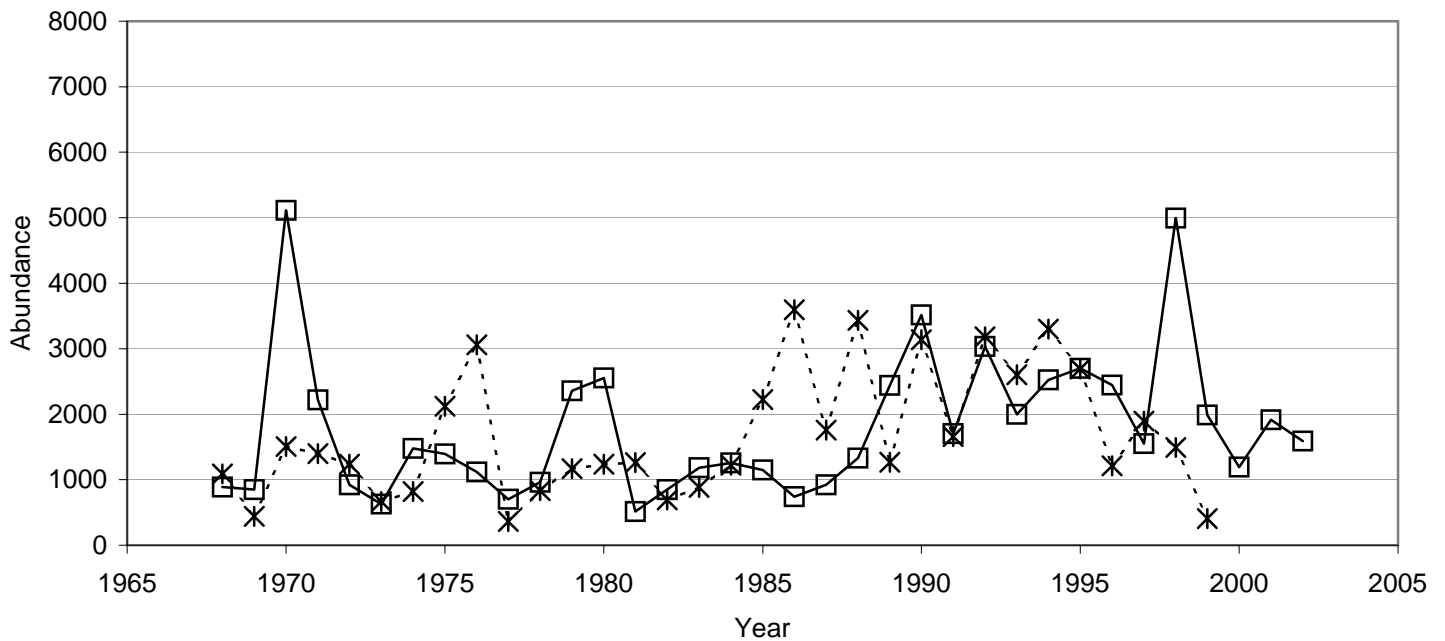
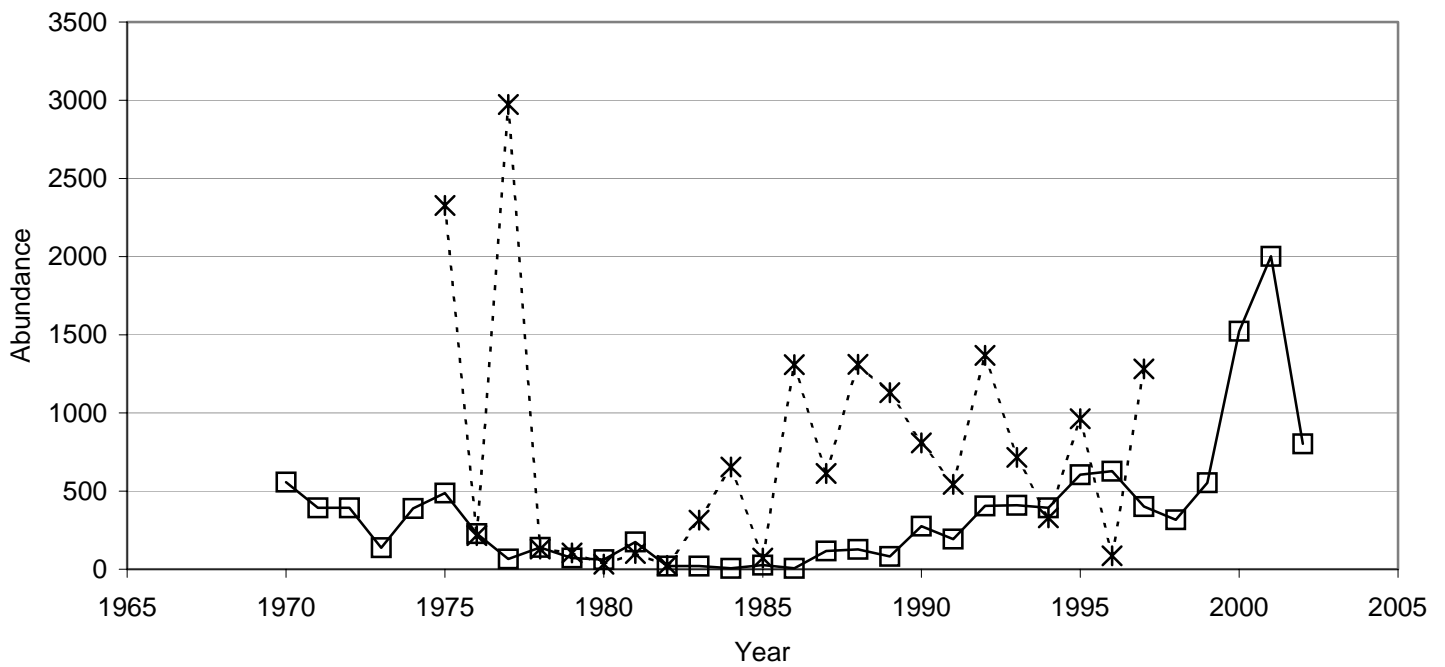


Figure A.2.4.2 Puget Sound Chinook pre-harvest recruits and spawners (cont.)

White



Nisqually

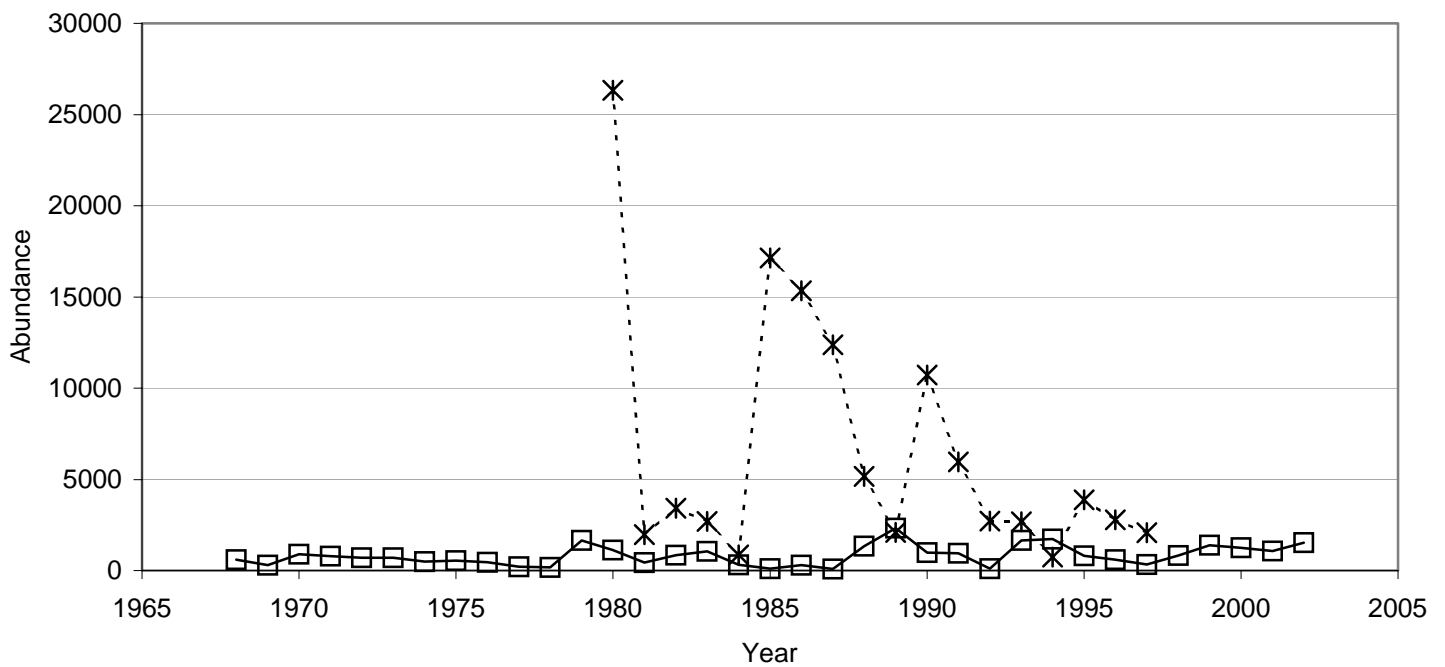
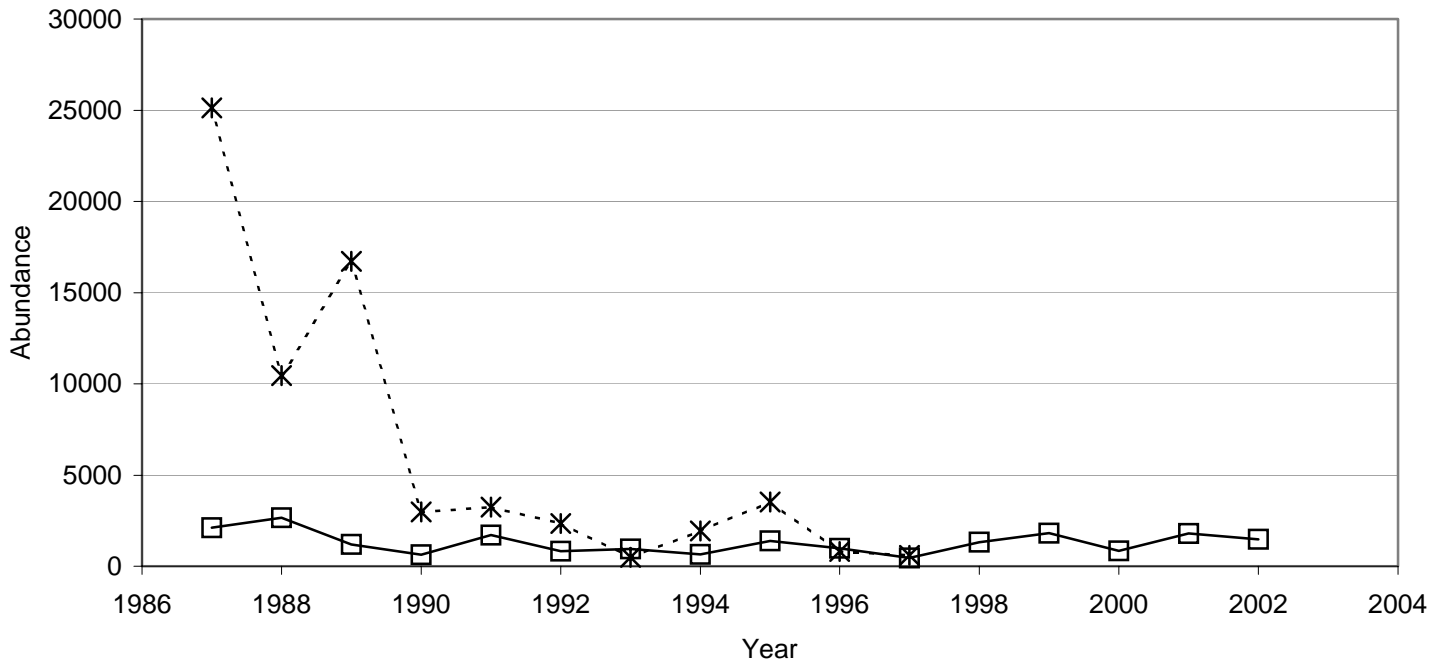


Figure A.2.4.2 Puget Sound Chinook pre-harvest recruits and spawners (cont.)

### Skokomish



### Dosewallips

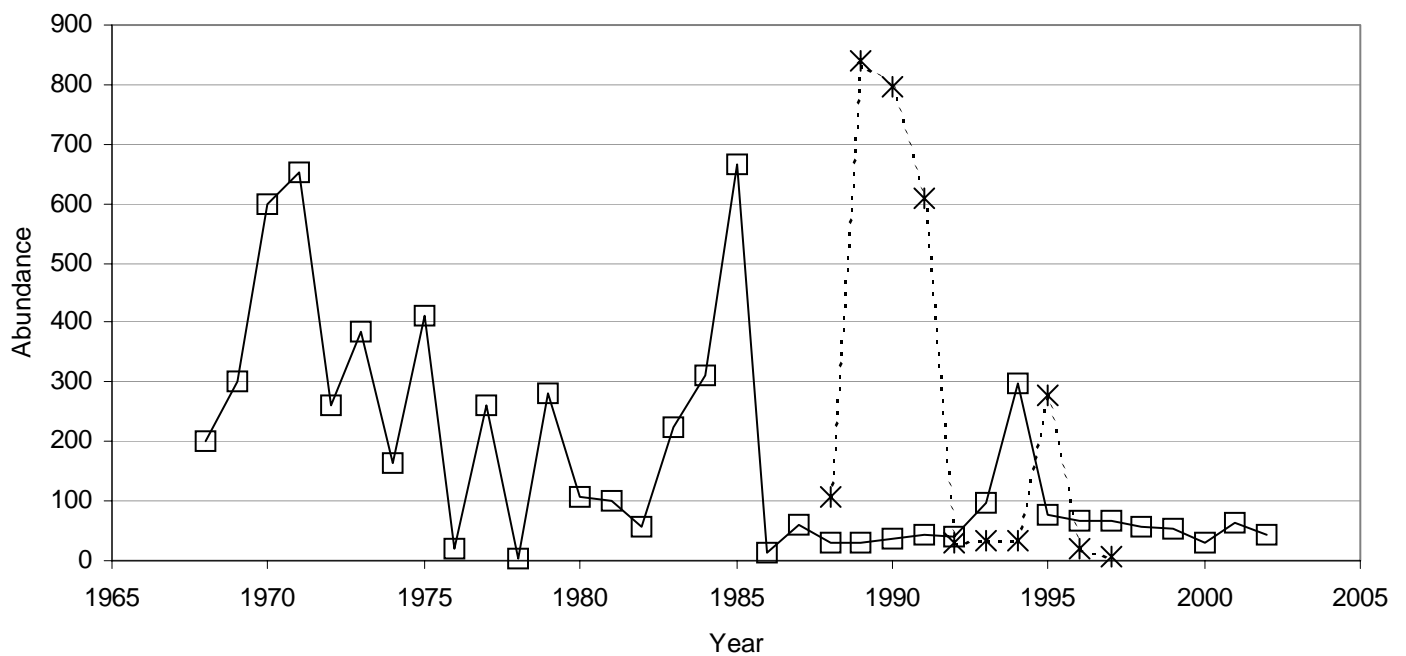
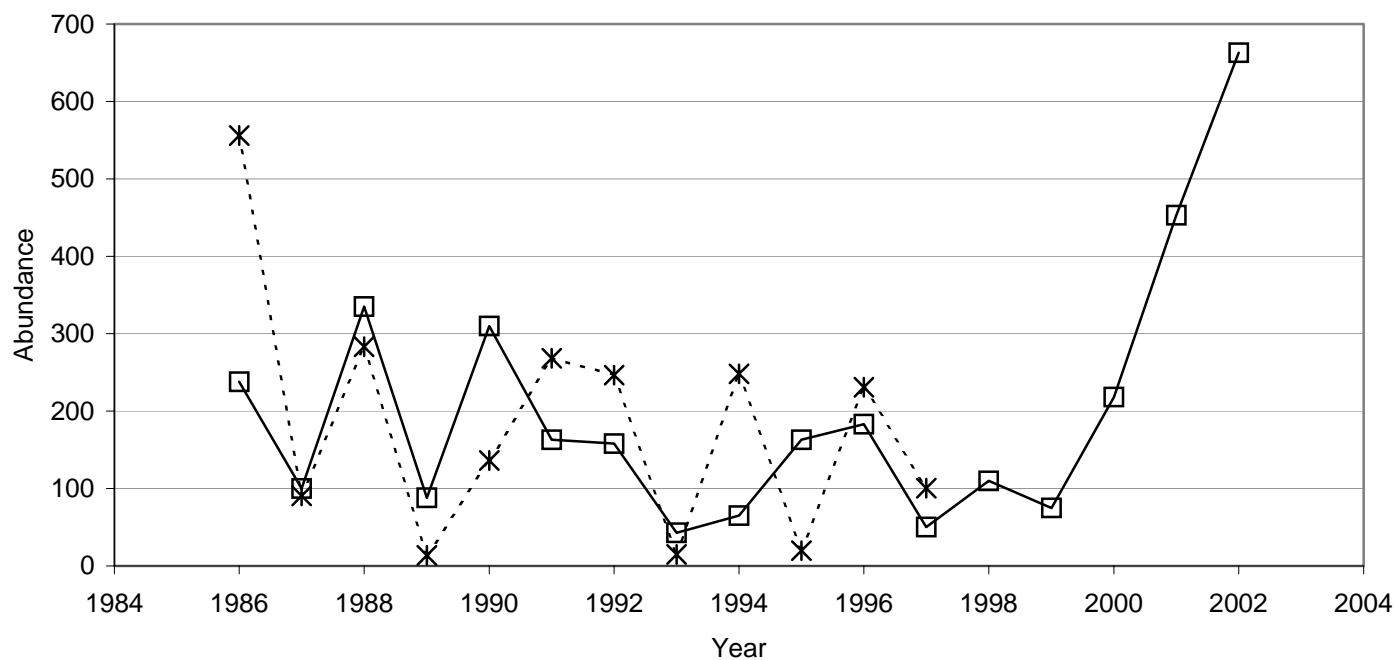


Figure A.2.4.2 Puget Sound Chinook pre-harvest recruits and spawners (cont.)

Dungeness



Elwha

